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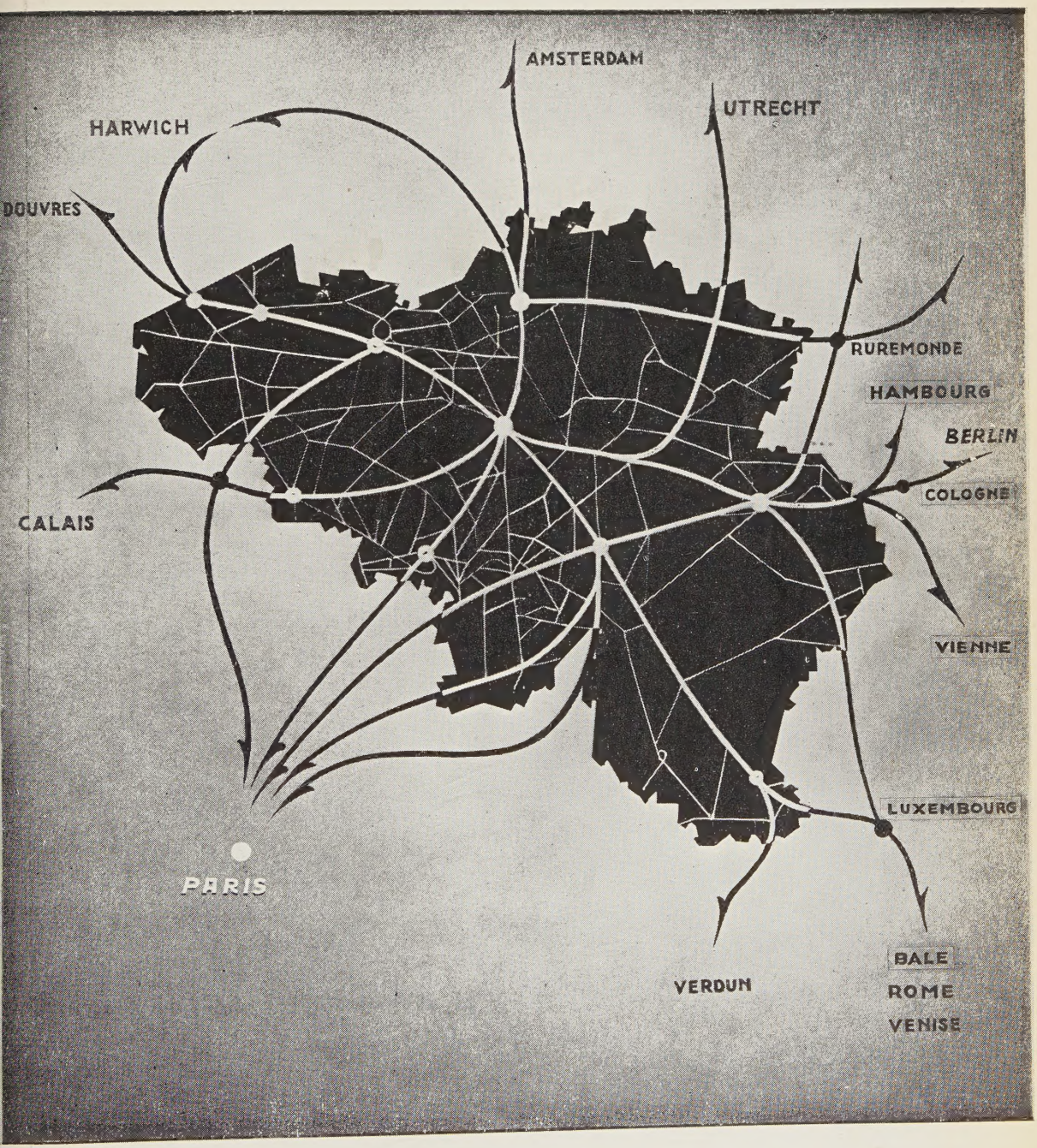
VOL. XXIV. — No. 2. FEBRUARY 1947

Monthly Bulletin of the International Railway Congress Association

(English Edition)

BELGIAN NATIONAL RAILWAYS



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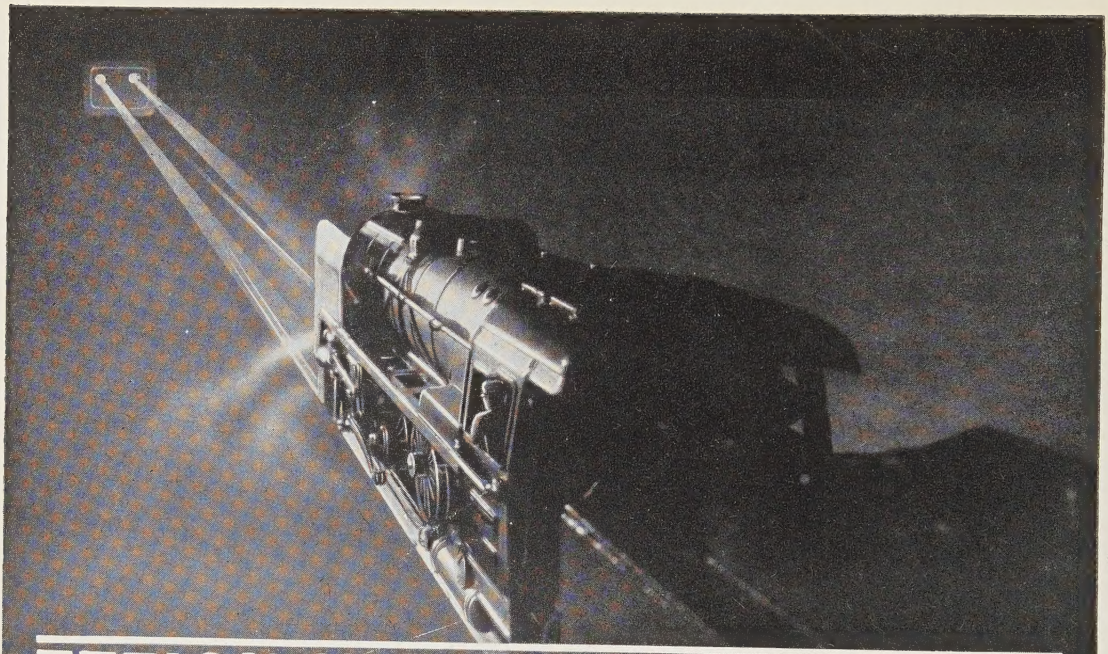

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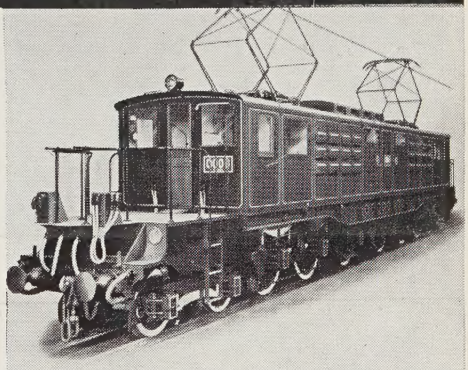

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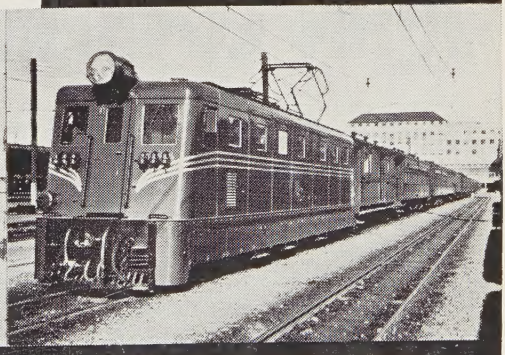

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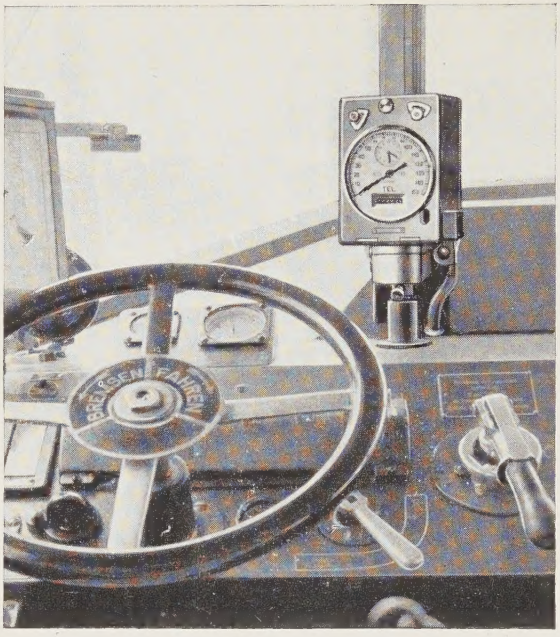

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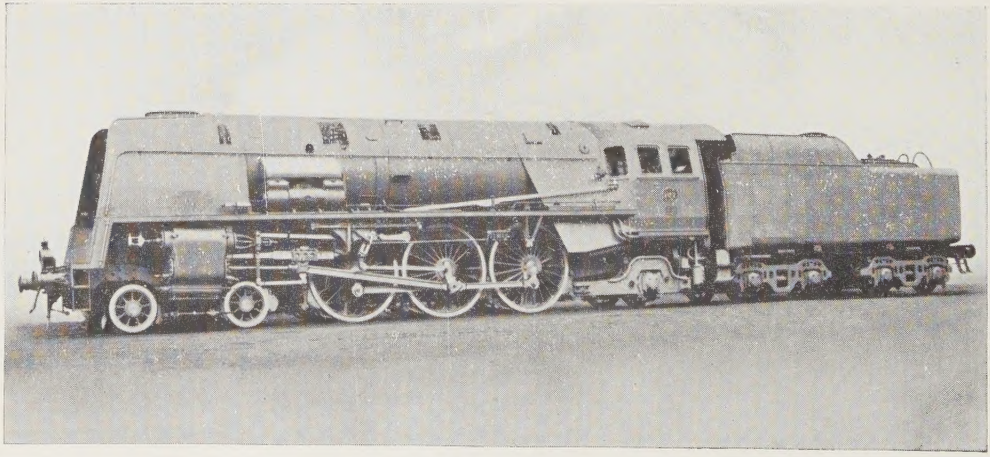

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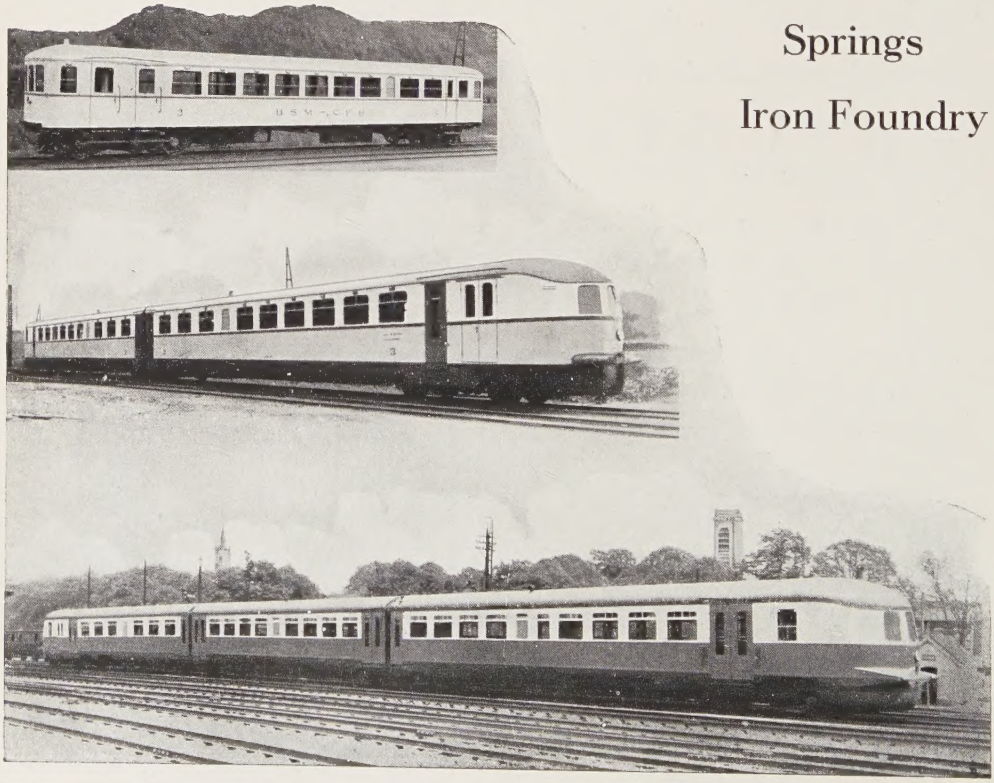

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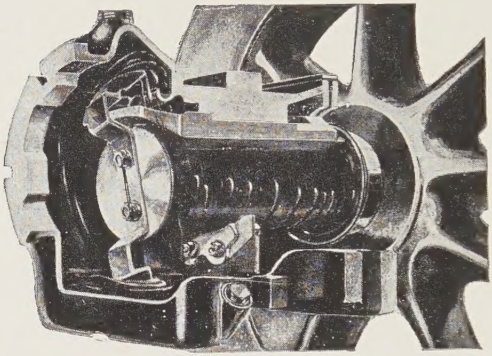

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MONTHLY BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

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An edition in French is also published.

VOL. XXIV. — No. 2. February 1947.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .2 & 669]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

14th. SESSION (LUCERNE, 1947).

QUESTION II.

Lightening the rolling stock.

Reduction in the weight of rolling stock (passenger and goods) by :

a) choice of the method of construction;

b) use of special steels;

c) use of alloys.

REPORT

(Belgium and Colony, Bulgaria, Denmark, Spain, Finland, France and Colonies, Greece, Hungary, Italy, Luxemburgh, Norway, Netherlands and Colonies, Poland, Portugal and Colonies, Rumania, Sweden, Switzerland, Czechoslovakia, Turkey and Jugoslavia),

by R. GUIGNARD,

Ingénieur à la Division de la Traction et des Ateliers
de la Direction générale des Chemins de fer fédéraux suisses (Berne).

Introduction.

In putting the question of the reduction of weight of rolling stock on the agenda for the 1947 Congress, the International Railway Congress Association wished to give expression to the great interest which, for more than ten years now, all railway managements have been taking in a question of the first importance for the future of transport by rail. The last occasion on which the question of all-metal construction of carriages and wagons was dealt with by the Congress was at the 12th Session at Cairo in 1933. At that date, the first designs in which a large use was made of the various welding processes for forming assemblies and of light alloys for certain internal fittings not subjected to any appreciable strains had just made their appearance, and even then a noticeable saving in weight was attained. Since then, we have witnessed a gradual development in design tending towards

a general reduction in dead weight, without either the safety or comfort of passengers, both indispensable to sound and satisfactory working, being in any way diminished. This progress has been characterised chiefly by developments in methods of construction, notably of the underframing and body as one unit, made possible by a general use of electric welding for uniting parts together and the ever increasing use of light weight metals and alloys. The adoption of steps like these has allowed constantly increasing and substantial savings of weight to be realised.

In the present report, we shall consider the light weight rolling stock produced in the course of the last ten years, or at present being built or designed, in the 22 European countries assigned to us. On account of the short time at our disposal, we have made large use of photographs and drawings — in any case much clearer to understand than long descriptions — and have limited our investigation, as regards passenger rolling stock, to vehicles able to enter without restriction into the make-up of any train whatsoever to be hauled by a locomotive. This means of course, that we have not dealt with rail motor coaches or railcars, whether operating singly or coupled to others, nor their special trailer vehicles. These were in fact the subject of a detailed investigation and report at the Paris Congress in 1937.

For the present paper, we have made use of particulars obtained by means of a detailed questionnaire sent to 42 Railway Administrations through the Association. Of these 27 replied; some 10 amongst them have no light weight rolling stock to report upon; as to the remainder, they have provided us with the particulars, details, drawings and photographs reproduced in these pages.

For additional clearness, we have felt it to be useful to devide our report into two main parts; passenger rolling stock and freight rolling stock. The first has been sub-divided in turn into several chapters as follows :—

A. *Passenger rolling stock.*

I. General considerations.
II. Construction of the underframe and body assembly.
III. Construction of the bogies.
IV. Fittings and accessories.
V. Results obtained in service.

B. *Freight rolling stock.*

A. PASSENGER ROLLING STOCK.

I. General considerations.

In this Chapter we shall consider the general characteristics brought together in Table I of the various types of light weight coaches, which have been brought to our notice, and the effects of the reduction in weight on the cost of haulage and in maintenance and initial expenditure.

Let us say at once that the problem of weight reduction is very closely bound up with that of the safety and comfort of passengers. All Administrations are agreed in admitting that no lightening of any vehicle may be obtained at the expense of these two factors, which appear *a priori* to be inconsistent with a reduction in weight, but which are and will long remain peculiarly characteristic of travel by rail. Many years experience have, however, proved, as we shall see in the last Chapter, that light weight vehicles offer riding qualities and a standard of safety at least equal, if not superior, to those possessed by their predecessors of heavier tare.

In Table I we have divided the dead weight of a vehicle into two parts, the first being the weight of the underframe and body assembly, with its fittings and accessories, the second being that of the bogies, with a view to

enabling a clearer comparison to be made between the various types of vehicle themselves, and the better to bring out to which part the process of weight reduction has been most thoroughly applied. In every country, it is the practice to compare the weights of vehicles by taking as the essential basis the weight per seat or per passenger capable of being carried. It should be noted that this takes no account of the amount of comfort offered to a passenger, that is of the space available per person. It does not allow of ascertaining the importance of the reduction in weight actually obtained with a given vehicle. For this reason, we have added a figure giving the weight per unit of overall length, which appears to us more useful than the first in arriving at a comparison between the rolling stock in service in the various countries under consideration.

In Table II, we have brought together the diagrams referring to some of the vehicles appearing in Table I.

The *Belgian National Railways* have not as yet built any light weight stock. Proposals are under consideration, at various stages of development, and divided into two distinct categories. In the first (Nos. 1 to 6, Table I) the steel framing of the vehicle design has been retained and various parts of like design lightened, such as the internal fittings, the buffing and draw gear etc. This procedure was chosen with the object of being able to place orders for rolling stock at once without having to get out new designs altogether. In this way a saving in weight of about 10 to 12 % on that of existing stock will be obtained. In the second category reductions will be effected in the weight of every component part, especially the body framing, the type of which has not yet been selected. The tare weights contemplated are 24 t. (23.620 Engl. tons) for the 18 m. (59′) coaches, Class AB, 22.5 t. (22.144 Engl. tons) for the 18 m. coaches class PwB, and 25 t. (24.605 Engl. tons) for the slow passenger stock 3rd class 2 C coaches, which effects a reduction in supplementary weight of about 30 % with respect to vehicles of the first category. The vehicles in which all parts have been subjected to weight reduction correspond to the same general arrangements (diagrams 1 and 3) as those of the first category. The 18 m. (59′) coaches are intended for the semi-fast trains, and the 22 m. (72′) ones for the through trains on services inside the country. The slow train coaches, class 2C, are to be used chiefly for workmen's trains.

In *Spain*, the Rolling Stock Standardisation Department undertook in 1941 the preparation of a design for new light weight coaches, in building which the difficulties of obtaining materials were to be allowed for. This was the reason why the use of light alloys and high tensile steel was ruled out. The design was to incorporate standardised sections and dispense with pressings of too large a size, so as to enable the vehicles to be supplied by several firms. It was also required to make use of the greatest number of interchangeable parts, similar to those used in the vehicles then running on the railway.

An initial order for 120 coaches was in this way given out, among five manufacturing concerns. This was followed at the beginning of 1944, by a second order for 200, giving a total of 320 coaches of different classes, as shown in Table I (Nos. 7 to 12). The dead weight varies according to the type of vehicle and averages 40 t. (39.368 Engl. tons). The conditions laid down prevented the builders from obtaining more than 15 to 20 % saving in weight over all-metal vehicles of the same type. When comparing the dead weights of these vehicles with those of coaches running in other countries, it is evidently necessary to bear in mind the more generous construction gauge ap-

Country and Administration.	No.	Class or type.	Number of vehicles.		Number of seats.				Part weight in t.	
			In service.	Under construct.	1	2	3	Total.	Underframe body & fittings.	Bogie.
Belgium. Belgian National Railways.	1	18m-AB	...	Not yet known.	12	44	...	56	24.1	10.8
	2	18m-PwB	...		...	38	...	38	21.7	»
	3	Omnibus 2C	...		...	...	128	128	25.1	»
	4	22m-AB	...		12	52	...	64	25.9	»
	5	22m-PwB	...		...	48	...	48	25.8	»
	6	22m-C	...		...	...	108	108	23.7	»
Spain. Spanish National Railways.	7	A	2	125	42	...	...	42	28.4	12.8
	8	AB	2	28	18	32	...	50	27.5	»
	9	AC	...	17	18	...	50	68	...	»
	10	B	...	46	...	64	...	64	...	»
	11	C	14	76	...	...	90	90	28.9	»
	12	CF	6	4	...	...	...	40	26.8	»
France. French National Railways.	13	A^8	3	...	48	...	...	48	23.1	12.9
	14	A^3B^5	2	...	18	40	...	58	22.6	»
	15	B^8	6	...	...	64	...	64	22.3	»
	16	C^{10}	26	...	...	...	80	80	23.6	»
	17	C^{11}	11	...	...	...	88	88	28.6	11.4
	18	C^5D	5	...	...	...	40	40	26.6	»
	19	C^3s	4	...	...	...	45	45	28.6	»
	20	$A^{2\,1/2}B^6$	...	350	15	48	...	63	23.2	9.8
	21	B^9c^9	...		...	72	...	72	24.2	»
	22	C^{10}	...		...	...	80	80	22.2	»
	23	AB^9	38	...	(72)	72	...	72	20.2	10.8
	24	C^{10}	85	...	...	...	94	94	20.2	»
	25	CD	47	...	...	...	76	76	20.7	»
	26	BD	...	100	...	48	...	48	19.2	9.8
	27	C	...		...	...	80	80	19.2	9.8
Hungary. State Railways.	28	Bak	1	...	...	54	...	54	23.7	10.2
	29	Cak	35	...	...	...	88	88	20.3	10.3
	30	ABa	1	...	12	30	...	42	25.9	13.1
	31	Ca	1	...	...	...	80	80	25.7	13.1
Italy. State Railways.	32	ABz	...	2	18	48	...	66	18.7	11.3
	33	Cz	10	370	...	...	80	80	20.7	11.3
North-Milan Railway.	34	820	6	...	32	...	56	88	14.0	8.0
	35	830	6	...	...	...	116	116	17.0	9.0
	36	C 1100	6	...	...	...	122	122	16.0	9.0
Poland. State Railways.	37	C	...	100	...	...	80	80	24.0	14.0
Rumania. Rumanian Railways.	38	CAFLD	20	...	...	...	72	72	20.2	8.0

of light weight metal coaches.

Tare in t.	*Unit weight in Kgr.*		*Total length over buffers.*	*Distance between bogie centres.*	*Bogie wheelbase.*	*Diameter of wheels.*	*Floor level.*	*Width of body.*	*Height above rail level.*	*Remarks.*
	Per seat.	*Per m. of total length.*								
			m.	*m.*	*m.*	*mm.*	*mm.*	*m.*	*m.*	
34.9	623	1 810	19.300	12.300			1 235	2.930		The tare weights given are those for the first class of vehicle. For the 2nd class the tare weights of Nos. 1, 2 and 3 will be 24.0, 22.5 and 25.0 t.
32.5	...	1 685					»	»		
35.9	280	1 610	22.255	14.595	2.50	1 010	1 225	2.866	3.950	
36.7	573	1 575	23.320	15.500			1 235	2.960		
36.6	...	1 570					»			
34.5	319	1 489					1 225			
41.2	982	1 930	21.350	14.280	2.50	1 006	1 277	3.100	4.035	
40.3	807	1 890								
...	...	...								
...	...	...								
41.7	463	1 955								
39.6	...	1 855								
36.0	750	1 545	23.263	15.343	2.50	920	1 190	2.943	3.945	Streamlined main line coaches of the « Ouest » area.
35.5	612	1 520								
35.2	550	1 515								
38.5	457	1 565								
40.0	455	1 700	23.530	15.500	2.50	920	1 270	2.940	4.000	Main line coaches of the « Est » area.
38.0	...	1 610								
40.0	890	1 700								
33.0	523	1 410	23.344	15.516	2.40	920	1 213	2.925	3.940	French National Railways streamlined main line coaches (1946 type).
34.0	470	1 455	23.304	15.476						
32.0	400	1 370	23.344	15.516						
31.0	430	1 420	21.815	14.200	2.50	920	1 239	2.960	3.965	Light-weight suburban coaches of the « Est » area (1936 type).
31.0	340	1 465	21.830							
31.5	...	1 440	21.830							
29.0	...	1 340	21.650	14.200	2.40	920	1 210	2.960	3.935	French National Railways Branch line coaches (1946 type).
29.0	362	1 340								
33.9	628	1 420	23.830	15.200	2.95	920	1 212	2.860	3.861	Main line coaches for internal traffic.
30.6	355	1 280	23.760							
39.0	929	1 735	22.460	15.000	2.50	1 020	1 274	2.916	3.918	Main line coaches for international traffic.
38.8	485	1 725								
30.0	455	1 250	23.980	16.520	2.80	1 010	1 240	2.864	3.984	
32.0	400	1 410	22.710	15.550						
22.0	250	970	22.720	16.020	2.70	900	...	2.900	3.700	Motor-coaches (voitures-pilote) for electrified lines.
26.0	224	1 145			2.70	980				
25.0	205	1 100			2.50	980				
38.0	475	1 690	22.420	15.400	2.80	1 000	1 238	2.910	3.978	
28.2	392	1 360	20.784	13.780	3.00	1 000	1 238	2.922	3.931	

TABLE I. — General characteristic

Country and Administration.	No.	Class or type.	Number of vehicles.		Number of seats.				Part weight in t.	
			In service.	Under construct.	1	2	3	Total.	Underframe body & fittings.	Bogie.
	39	Ao3	...	1	6	24	...	30	30.4	12.6
	40	ACo	...	20	14	...	20	34	31.4	»
	41	Co14	...	9	...	...	52	52	30.4	»
	42	Ro3	1	2	...	...	48	48	32.4	»
Sweden.	43	Bo4b	...	3	...	48	...	48	28.4	11.6
State Railways.	44	Bo5b	4	3	...	48	...	48	27.8	»
	45	BCo7b	3	11	...	20	46	66	27.2	»
	46	BCo11b	2	3	...	12	64	76	27.7	»
	47	Co8b	15	10	...	...	82	82	27.6	»
	48	Co8c	18	8	...	...	78	78	28.3	»
	49	Co8d	86	...	...	...	86	86	26.1	»
	50	Co8f	...	15	...	...	78	78	25.8	»
	51	Co9b	21	...	...	...	80	80	27.3	»
	52	CFo4	5	...	...	...	32	32	24.7	»
	53	Co6	129	26	...	...	98	98	19.3	11.6
Stockholm-Roslagens (private Railway).	54	Co	4	...	...	...	78	78	13.5	5.4
	55	Co	7	...	...	...	70	70	13.3	5.4
Switzerland. Federal Railways.	56	$B^4\ddot{u}$	23	5	...	48	...	48	21.1	7.2
	57	$BC^4\ddot{u}$	15	5	...	24	31	55	21.1	»
	58	$C^4\ddot{u}$	70	20	...	...	72	72	20.3	»
	59	$AB^4\ddot{u}$	8	25	12	30	...	42	21.1	7.7
	60	$C^4\ddot{u}$	1	...	...	...	72	72	21.3	7.5
	61	$Dr^4\ddot{u}$	10	4	...	...	52	52	25.2	7.2
	62	$B^4\ddot{u}$	...	5	...	34	...	34	9.4	4.1
	63	$BC^4\ddot{u}$	4	...	...	23	28	51	9.1	»
	64	$C^4\ddot{u}$	10	8	...	...	68	68	8.5	»
	65	BCF^4	...	5	...	16	32	48	14.3	6.7
	66	BC^4	...	3	...	24	32	56	13.3	»
	67	C^4	...	3	...	...	64	64	12.3	»
Berne-Lotschberg-Simplon.	68	C^4	13	...	...	...	80	80	15.0	8.3
South-Eastern Railway.	69	$C^4\ddot{u}$	2	...	...	...	80	80	15.0	7.2
Rhaetian Railways.	70	$AB^4\ddot{u}$	2	...	15	21	...	36	12.0	4.0
	71	$C^4\ddot{u}$	6	...	...	...	68	68	11.0	4.0
Montreux-Bernese Oberland.	72	$ABC^4\ddot{u}$	3	...	6	6	47	59	10.3	4.4
	73	$C^4\ddot{u}$	2	...	...	...	66	66	9.9	4.4
Jugoslavia. State Railways.	74	Cah	...	50	...	...	64	64	...	...

of light weight metal coaches.

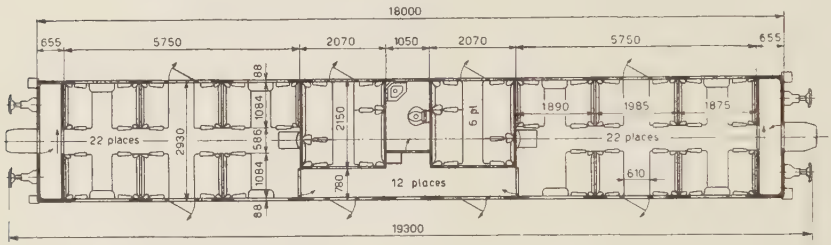
Tare in t.	Unit weight in Kgr.		Total length over buffers.	Distance between bogie centres.	Bogie wheelbase.	Diameter of wheels.	Floor level.	Width of body.	Height above rail level.	Remarks.
	Per seat.	Per m. of total length.	m.	m.	m.	mm.	mm.	m.	m.	
43.0	1 430	1 785	24.100	16.600	2.40	980	1 260	3.134	4.070	Sleeping-cars.
44.0	1 295	1 870								
43.0	827	1 830	23.500	16.600	2.40	980	1 260	3.134	4.070	Sleeping-cars.
45.0	938	1 915								Restaurant-cars.
40.0	833	1 700								
39.4	820	1 675								
38.8	588	1 650								
39.3	517	1 670								
39.2	478	1 665	23.500	16.000	3.00	980	1 260	3.134	4.070	Main line coaches.
39.9	512	1 700								
37.7	438	1 605								
37.4	480	1 590								
38.9	486	1 655								
36.3	...	1 545	23.500	16.000	3.00	980	1 260	3.014	4.070	
30.9	315	1 410	21.900	15.000	3.00	980	1 245	3.134	3.715	Suburban coaches.
18.9	242	993	19.050	13.100	1.90	770	1 010	2.600	3.435	Narrow gauge.
18.7	267	983								
28.3	590	1 250		16.770						Light-weight steel coaches with central corridor.
28.3	515	1 250	22.700	16.770	2.70	900	1 000	2.920	3.700	
27.5	382	1 210		17.000						
28.8	685	1 270	22.700	16.400	2.70	900	1 100	2.920	3.752	Light-weight steel coaches with side corridor.
29.0	405	1 280		16.950						
32.4	625	1 430	22.700	17.000	2.70	900	1 100	2.920	3.700	Light-weight steel restaurant-car.
13.5	397	820	16.470	11.800	1.80	700	872	2.655	3.402	Light-weight coaches for the Brünig line. 1 m. narrow gauge line.
13.2	260	800								
12.6	187	765								
21.0	438	970	21.700	15.600						Light-weight coaches for secondary lines.
20.0	358	1 085	18.400	12.300	2.30	900	1 193	2.950	3.700	
19.0	297	1 030	18.400	12.300						
23.3	292	1 140	20.460	14.760	2.70	920	1 186	3.000	3.748	Open platforms.
22.2	278	1 060	21.000	15.000	2.70	900	1 000	2.970	3.620	Centre platform.
16.0	445	908	17.630	12.830	2.00	750	900	2.650	3.330	1 m. narrow gauge line.
15.0	221	850								
14.7	250	890	16.520	11.250	2.10	750	887	2.668	3.200	1 m. narrow gauge line.
14.3	216	865								
32-35	523	1 710	19.600	13.000	2.20	1 080	1 240	2.870	3.940	

TABLE II.

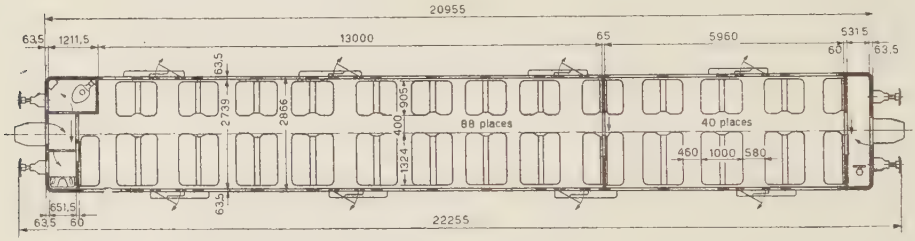
Diagrams of the principal light weight metal coaches.

(The numbers of the diagrams correspond to those of Table I.)

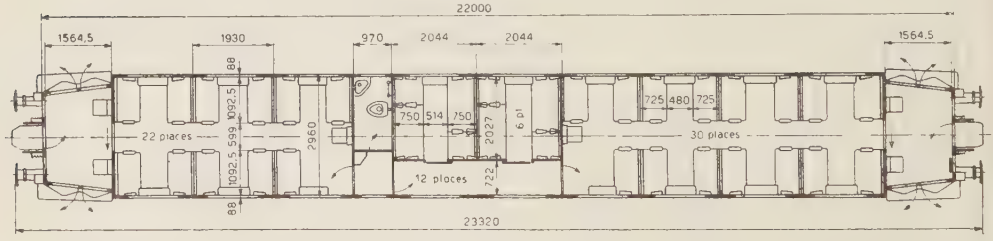
Belgian National Railways.



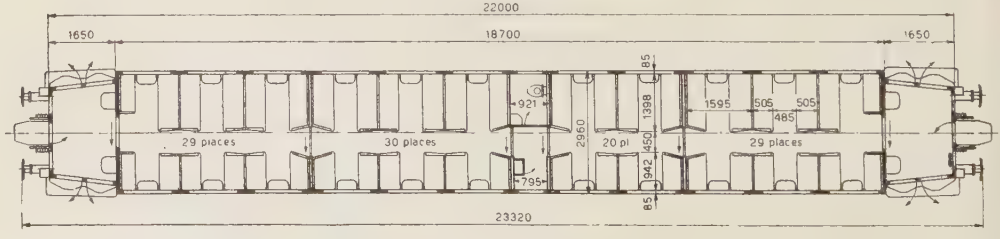
1. 18 m. (60′) class AB coach. 56 seats. 34.9 t. (34.348 Engl. tons).



3. Stopping train class 2 C coach. 128 seats. 35.9 t. (35.332 Engl. tons).



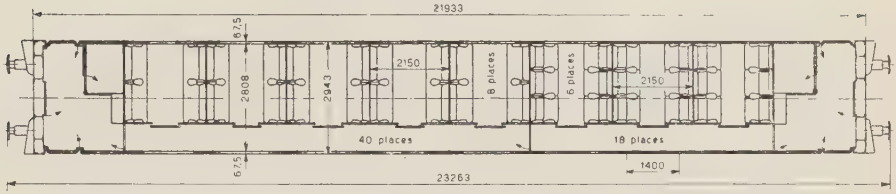
4. Class AB main line coach, 22 m. (72′). 64 seats. 36.7 t. (36.12 Engl. tons).



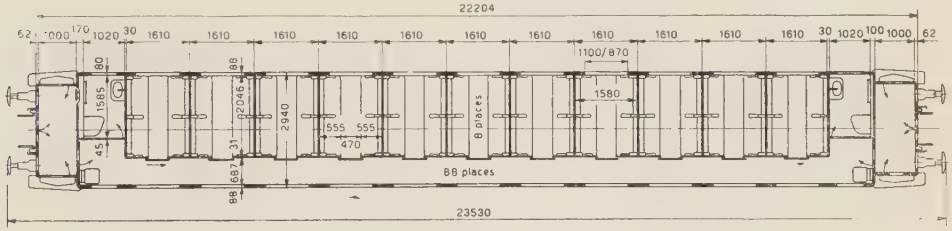
6. Class C main line coach, 22 m. (72′). 108 seats. 34.5 t. (33.955 Engl. tons).

TABLE II. *(Continued.)*

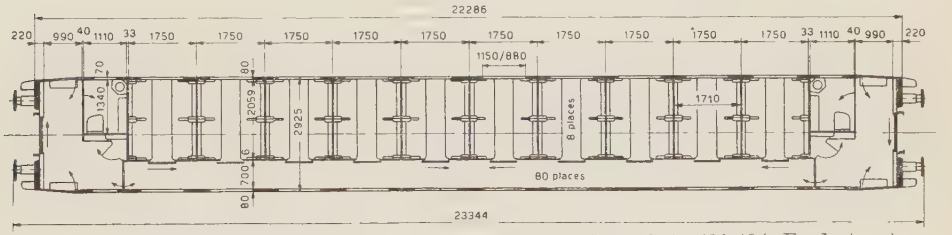
French National Railways.



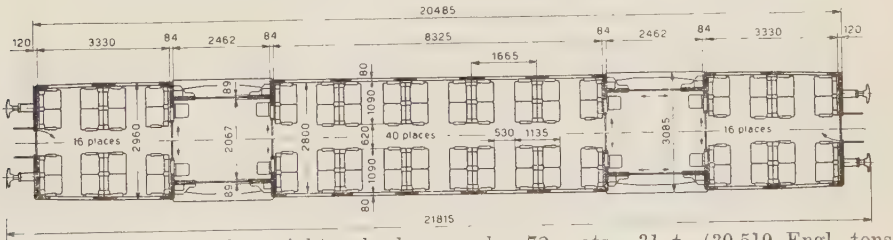
14. Class A^3B^5 (Ouest) streamlined main line coach. 58 seats. 35.5 t. (34.939 Engl. tons).



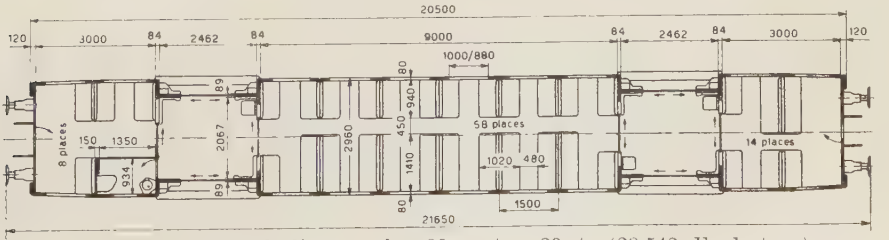
17. Class C^{11} main line coach (Est). 88 seats. 40 t. (39.368 Engl. tons).



22. Class C^{10} streamlined main line coach. 80 seats. 32 t. (31.494 Engl. tons).



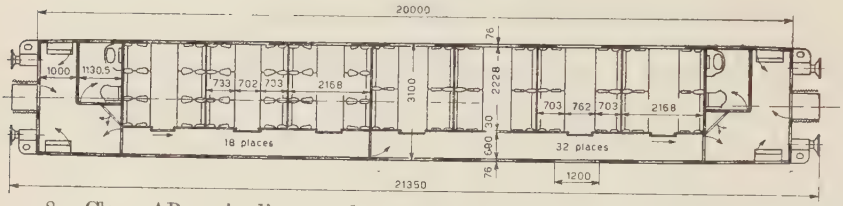
23. Class AB^9 (Est) light weight suburban coach. 72 seats. 31 t. (30.510 Engl. tons).



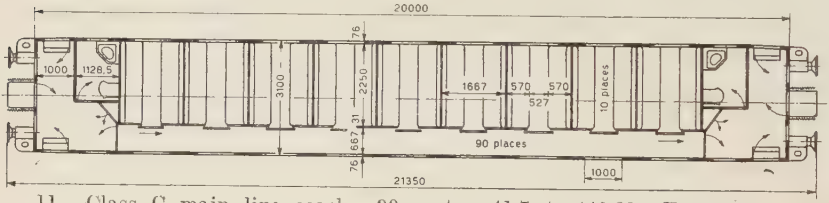
27. Class C branch line coach. 80 seats. 29 t. (28.542 Engl. tons).

TABLE II. *(Continued.)*

Spanish National Railways.

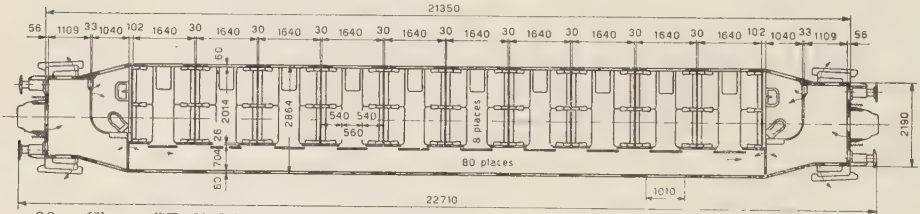


8. Class AB main line coach. 50 seats. 40.3 t. (39.663 Engl. tons).



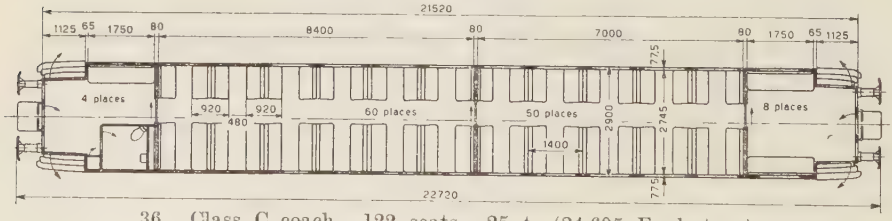
11. Class C main line coach. 90 seats. 41.7 t. (40.814 Engl. tons).

Italian State Railways.



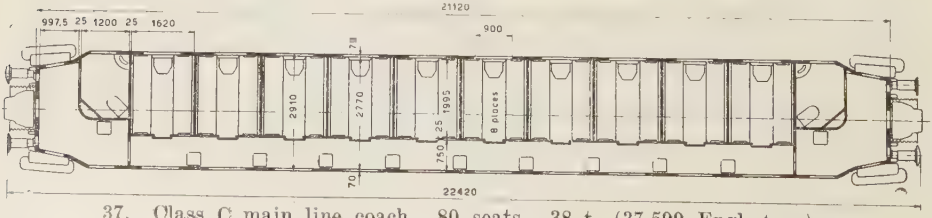
33. Class CZ light-weight coach (1940). 80 seats. 32 t. (31.494 Engl. tons).

North-Milan Railways.



36. Class C coach. 122 seats. 25 t. (24.605 Engl. tons).

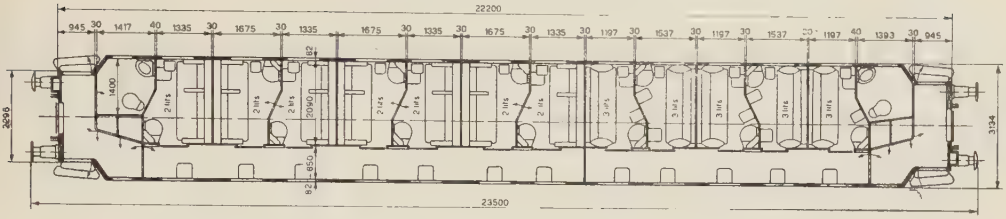
Polish State Railways.



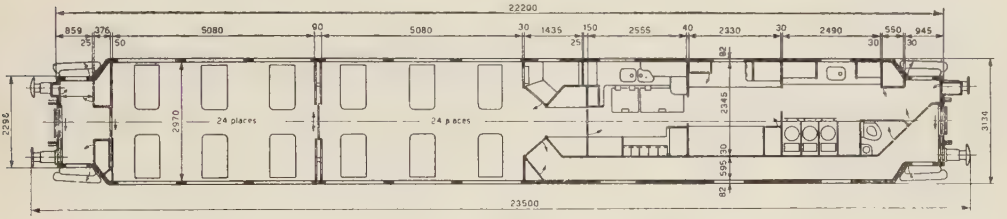
37. Class C main line coach. 80 seats. 38 t. (37.599 Engl. tons).

TABLE II. *(Continued.)*

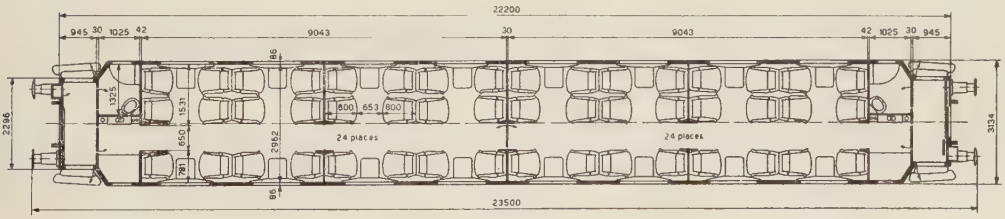
Swedish State Railways.



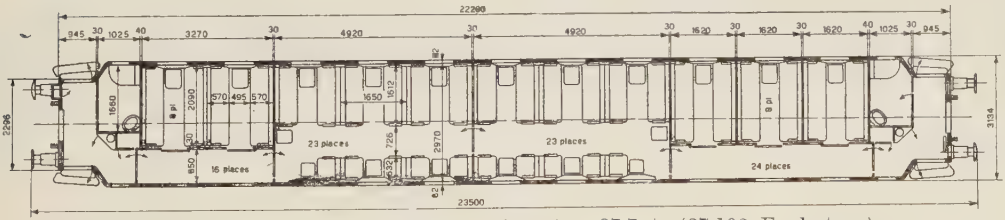
40. Class ACo sleeping-car. 34 seats. 44 t. (43.305 Engl. tons).



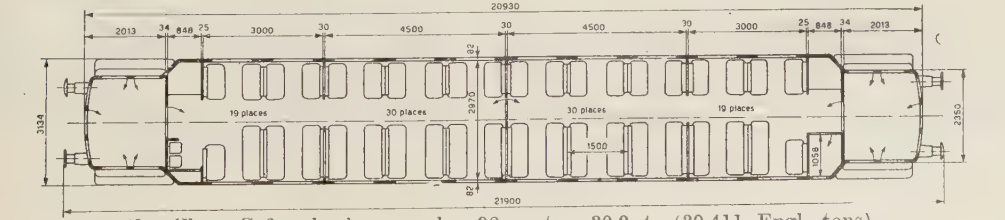
42. Class Ro3 restaurant car. 48 seats. 45 t. (44.289 Engl. tons).



44. Class Bo5b main line coach. 48 seats. 39.4 t. (38.777 Engl. tons).



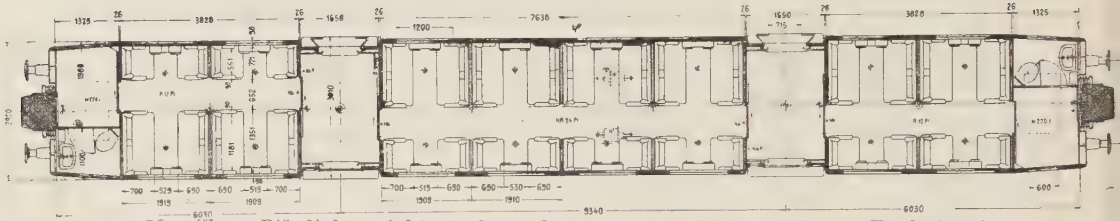
49. Class Co8d main line coach. 86 seats. 37.7 t. (37.103 Engl. tons).



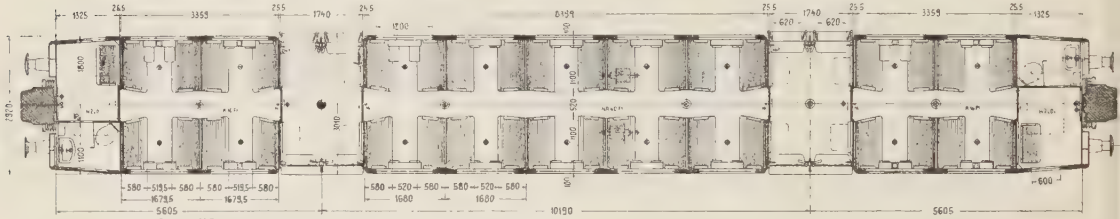
53. Class Co6 suburban coach. 98 seats. 30.9 t. (30.411 Engl. tons).

TABLE II. *(Continued.)*

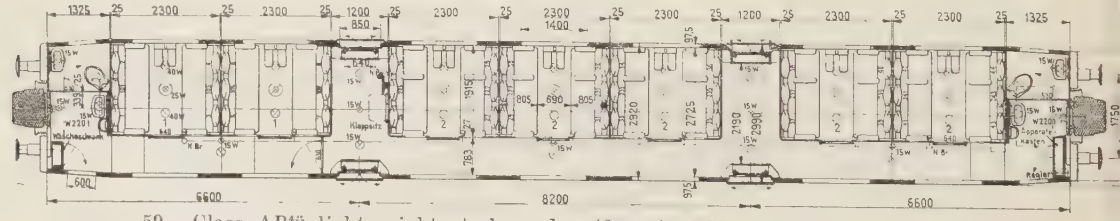
Swiss Federal Railways.



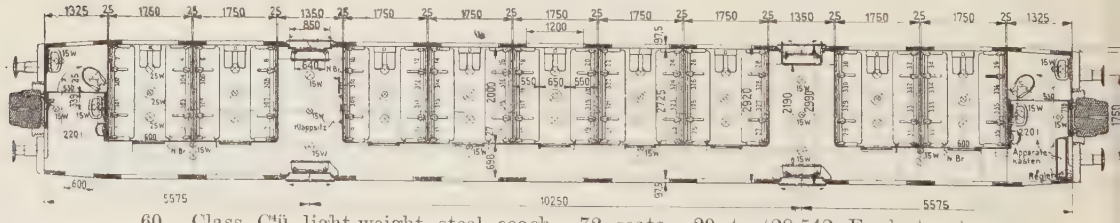
56. Class B⁴ü light-weight steel coach. 48 seats. 28.3 t. (27.852 Engl. tons).



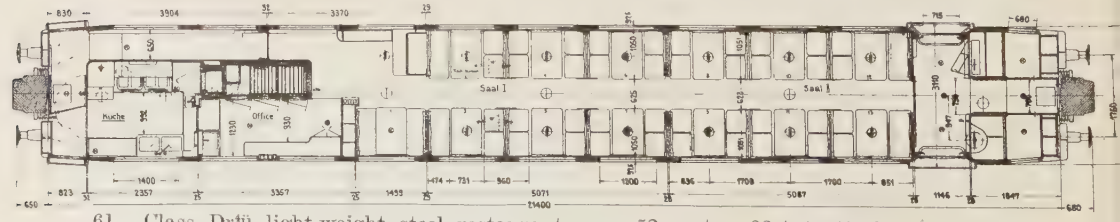
58. Class B⁴ü light-weight steel coach. 72 seats. 27.5 t. (27.065 Engl. tons).



59. Class AB⁴ü light-weight steel coach. 42 seats. 28.8 t. (28.344 Engl. tons).



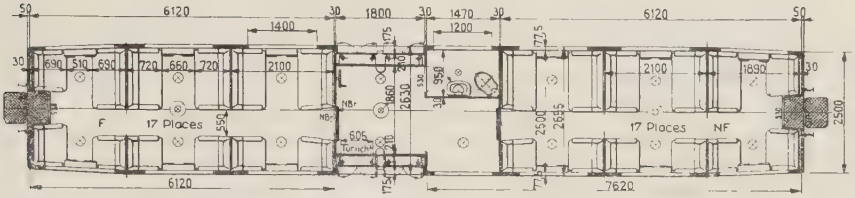
60. Class C⁴ü light-weight steel coach. 72 seats. 29 t. (28.542 Engl. tons).



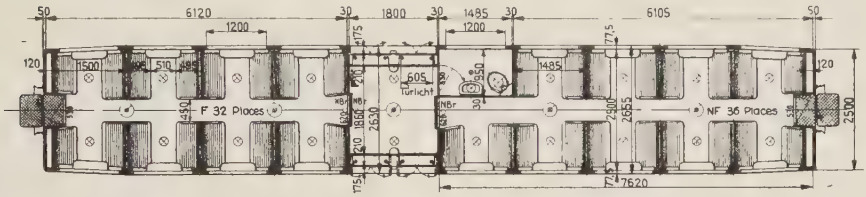
61. Class Dr⁴ü light-weight steel restaurant car. 52 seats. 32.4 t. (31.887 Engl. tons).

TABLE II. *(Continued.)*

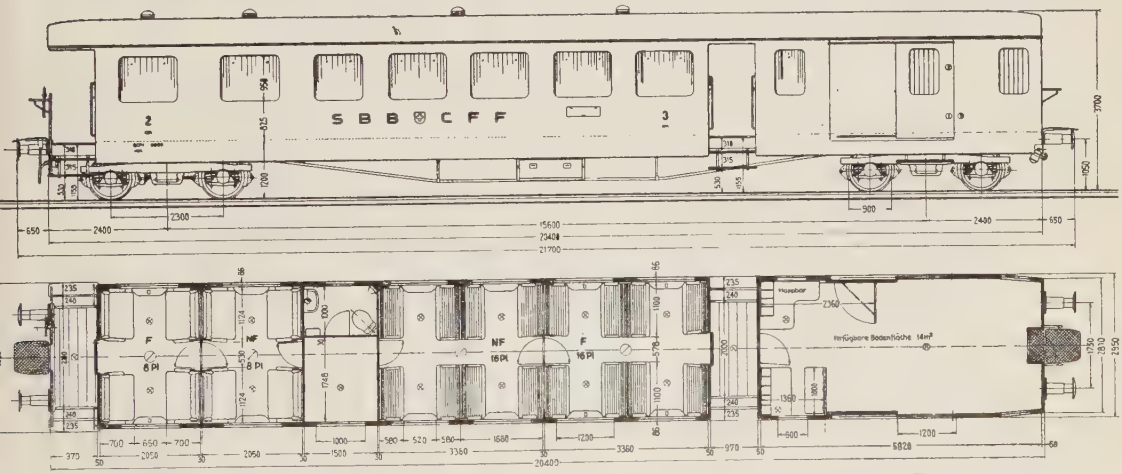
Swiss Federal Railways. (Continued.)



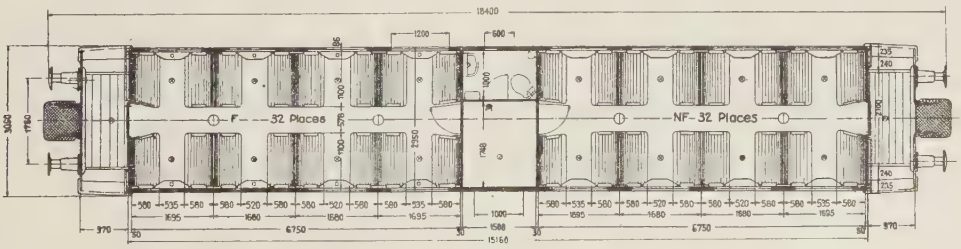
62. Class B⁴ü light-weight coach for the Brünig line. 34 seats. 13.5 t. (13.286 Engl. tons).



64. Class C⁴ü light-weight coach for the Brünig line. 68 seats. 12.6 t. (12.4 Engl. tons).



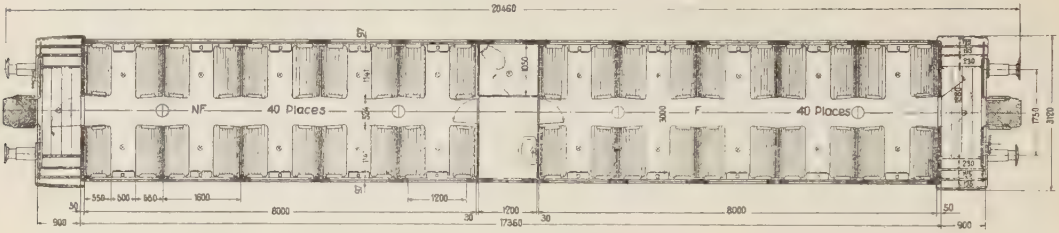
65. Class BCF⁴ light-weight coach for secondary lines. 48 seats. 21 t. (20.668 Engl. tons).



67. Class C⁴ light-weight coach for secondary lines. 64 seats. 19 t. (18.699 Engl. tons).

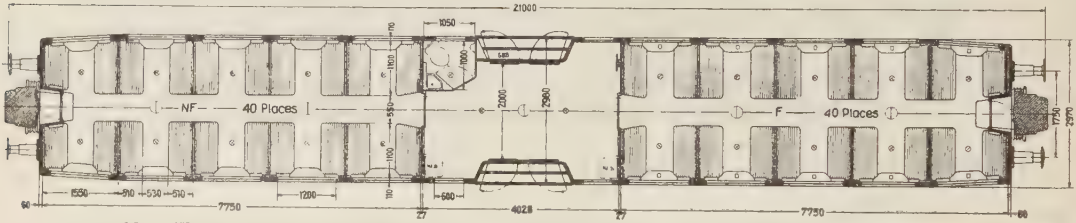
TABLE II. *(Continued.)*

Berne-Loetschberg-Simplon Railway (Switzerland).



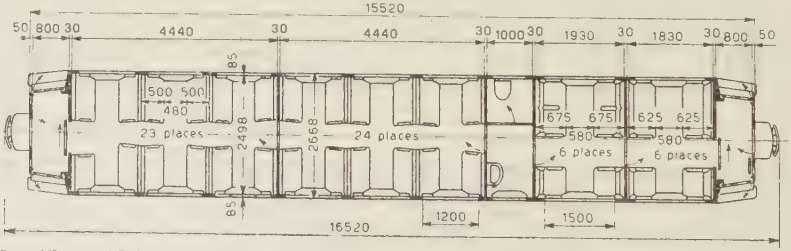
68. Class C^4 light-weight steel coach. 80 seats. 23.3 t. (22.931 Engl. tons).

South-Eastern Railway (Switzerland).



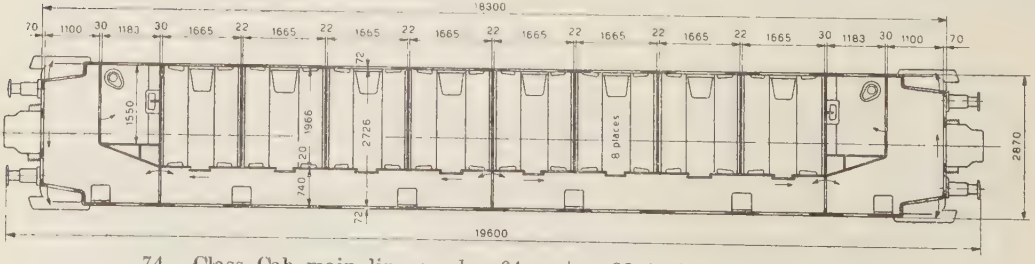
69. Class $C^4ü$ light-weight steel coach. 80 seats. 22.2 t. (21.85 Engl. tons).

Montreux-Bernese Oberland Railways (Switzerland).



72. Class $ABC^4ü$ light-weight coach. 59 seats. 14.7 t. (14.466 Engl. tons).

Jugoslavian State Railways.



74. Class Cah main line coach. 64 seats. 32 t. (31.494 Engl. tons).

plying to the Spanish coaches, resulting from the broader track gauge. The width of the body is in consequence about 180 mm. ($7^{3}/_{32}''$) greater than the figure usually met with.

These new coaches (Fig. 1), a certain number of which are already in service, are used in making up the long distance trains on the main routes and are suitable for the maximum speed of 130 km. (81 miles) per hour.

In *France*, between 1935 and 1938, a first step of great importance in the process of weight reduction was effected by the various railway systems, who produced the following vehicles :—

1. The light weight suburban coaches of the French Est Ry, 1936 type (Fig. 2) built on the tubular or box girder plan, put into practice for the first time by the Design Department of that Company in 1929. The dead weight of the AB^{9} and C^{10} type coaches is 31 t. (30.510 Engl. tons), which represents a reduction in weight of 25 to 28 %, compared with the tare figures of 41.5 and 43 t. (40.844 and 42.320 Engl. tons) of vehicles of the same kind built in 1930. The purpose of these coaches was to cope with the increase of traffic on the suburban lines running out of Paris-Est without having to obtain costly locomotives which would have had to be more powerful than those then in service. Altogether, 170 coaches of the series AB, C and CD were put into service from 1937 to 1939 (Nos. 23 to 25 of Table I and diagram 23).

2. The streamlined coaches belonging to the main lines of the former State Railways, produced by its engineers working in collaboration with the « Entreprises Industrielles Charentaises ». Their weights vary between 35.2 t. (34.645 Engl. tons) for the B^{8} and 36.5 t. (35.923 Engl. tons) for the C^{10}, which gives a mean weight reduction of 25 % with respect to the all-metal vehicles of 1930 to 1935. Fig. 3 gives an outside view of one of these coaches having a highly streamlined form. Altogether 52 of this type have been built, the first of which were put into service in 1936 (Nos. 13 to 16, Table I). They were intended to replace the O.C.E.M. type vehicles of 45 to 50 t. (44.289 to 49.210 Engl. tons) used to form set trains for the extra high speed services on the Paris-Le Havre line.

3. The main line coaches, type C^{11} of the Est Railways (Fig. 4) built in accordance with the same principles as the suburban coaches already referred to, having a dead weight of 40 t. (39.568 Engl. tons), or some 10 t. (9.842 Engl. tons) less than those of the 1929 type. The 20 vehicles shown in Table I (Nos. 17-19) were put into service in 1939.

4. The O.C.E.M. coaches, which retain the principles of using the walls of the vehicle to provide part of the structural resistance but are almost entirely welded, simplified and lightened. The dead weight of the type C^{10} coach is some 41.5 t. (40.844 Engl. tons) only.

5. The main line vehicles C^{10} and $A^{3}B^{6}$ of the Nord Railway of which the dead weights are 44 and 43 t. (43.305 and 42.320 Engl. tons) respectively, a saving of 5 or 4 t. (4.921 and 3.936 Engl. tons) over the preceding designs. It should be pointed out that the reduction in weight in the C^{10} type was obtained notwithstanding that the underframe had been made 1 m. 40 ($4'7^{1}/_{8}''$) longer in order to give passengers more comfort. The assembly of the underframe and body forms a tubular girder, in continuation of the principle adopted by this railway system in 1926.

We may mention also, for the sake of completeness, the building in 1934-1935 at the Helemmes workshops of the French Nord of an articulated set made up of three coaches carried on four bogies. Each coach is in the form of a lattice girder framework supporting a light metal streamlined body. The two end vehicles accommodate 98 passengers seated and 90 standing, the centre one 78 and 80 respectively, giving 274 seats and standing room for 260 passengers in the set, for a dead weight of 275 kgr. (606 lb.) per seat. The total weight reduction achieved in comparison with the all-steel stock (440 kgr. [970 lb.] per seat) is thus 37.5 %. The Nord Company accordingly decided in 1938 to build a new unit, made up of a double articulated vehicle of tubular

Spanish State Railways.

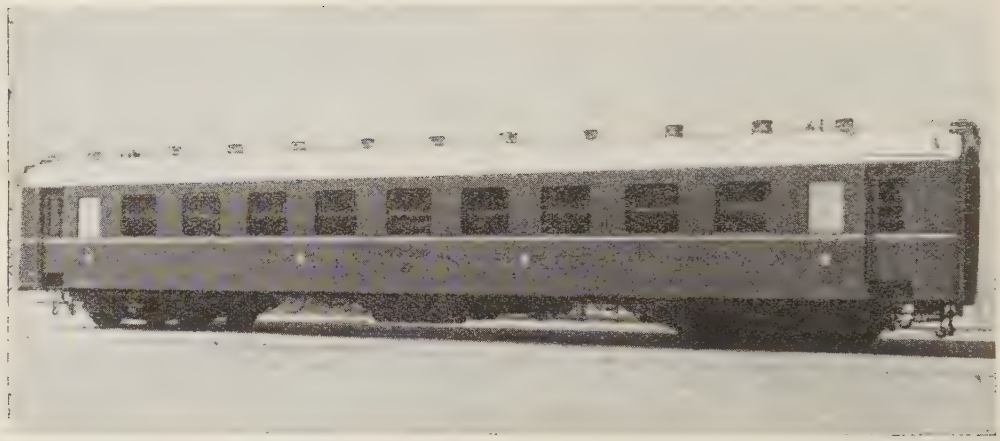


Fig. 1. — Class C main line coach.

French National Railways.

Fig. 2. — Class AB^{9} light-weight suburban coach (Est).

French National Railways.

Fig. 3. — Class A^8 streamlined main line coach (Ouest).

Fig. 4. — Class C^{11} main line coach (Est).

construction, entirely in light weight material. Its construction was interrupted by the war.

Since the formation of the French National Railways in 1938, the Management continued the investigations into the tubular designs used on the former Est Railway, but the war prevented any actual work being done.

In a second stage in this process, at present under way, two types of vehicles have been put into construction, as follows:—

2. The so-called branch line coaches, intended for service on secondary lines, of which 100 are now being built (Nos. 26 and 27, Table I, diagram 27). The design and appearance are substantially the same as those of the 1936 type suburban coaches. The dead weight will amount to 29 t. (28.542 Engl. tons) without electric heating equipment; the latter will add about 1 t. (0.984 Engl. ton) more. Compared with the 1936 type, the weight of which had itself been appreciably reduced, an additional saving of some 2 t. (1.968 Engl. tons) will be obtained in the case of the 3rd class coach, or 6.5 %.

French National Railways.

Fig. 5. - Class C^{10} main line streamlined coach.

1. The streamlined main line coaches, intended to enable the high speed long distance services gradually to be put into operation again. A total of 350 coaches of types $A^{2\,1/2}B^{6}$, $B^{9}C^{9}$ and C^{10} are under construction (Nos. 20 to 22 of Table I and diagram 22). Fig. 5 is an outside view of this vehicle, which has a simple streamlined form with the ends slightly tapered off. The calculated tare weight is from 32 to 34 t. (31.494 tot 33.463 Engl. tons) according to type. There is an 8 t. (7.873 Engl. tons) saving in weight with the C^{10} type, compared with the C^{11} Est type of 1938, weighing 40 t. (39.368 Engl. tons), or 20 %.

The S.N.C.F. considers that all its light weight metal coaches are suitable for speeds up to 130 and even 140 km. (81 to 87 miles) per hour.

We have now to mention the conversion to metal construction of a number of coaches having wooden bodies, running in the Western, South-Western, and Eastern districts, a process which does not lend itself particularly to any saving in weight, all existing parts being used, in principle, to the utmost possible extent. This conversion, effected when a coach is sent

in for heavy repairs, consists in replacing the wooden body by an all metal welded one, usually of the tubular girder type. It is considered that it pays to do this, for the additional cost it occasions is justified by the definite increase obtained in the life of the vehicle and an indisputable raising of the standard of safety for passengers. The problem has to be approached, however, separately for each type of vehicle, since in order to avoid having to make alterations in the springing and bogies, care has to be taken to see that the dead weight of the metal bodied vehicle does not differ materially from what it was in the original form. We have observed that there is an increase of weight in the Western and South-Western vehicles of some 2 500 to 3 000 kgr. (2.460 to 2.952 Engl. tons) as a consequence of this conversion, an amount of no great concern, in view of the essentially useful character of the operation, for the coaches so dealt with offer a resistance to damage comparable with that of the best all-metal vehicles. Figs. 6 and 7 give, by way of illustration, the outside views of a Western district coach before and after conversion.

In *Hungary*, the State Railways built in 1942 a first batch of light weight coaches, intended for service inside the country, one type Bak coach and 35 type Cak (Fig. 8), the dead weights being 33.9 and 31.2 t. (33.363 and 30.706 Engl. tons) respectively (Nos. 28 and 29, Table I). The saving obtained amounts to 3.6 t. (3.542 Engl. tons) or 9.6 % for the Bak and 6.2 t. (6.101 Engl. tons) or 16.5 % for the Cak type. The second series comprises coaches of the ABa and Ca types, of which one of each has been running since 1944. The dead weights of these vehicles, intended for the international services, amount respectively to 39 and 38.8 t. (38.384 and 38.186 Engl. tons), saving respectively 5.4 and 6.6 t. (5.314 and 6.495 Engl. tons) compared with the metal vehicles previously in use (Nos. 30 and 31, Table I). The underframe, the side and end walls, and roof, form a girder of tubular form, welded throughout. These coaches can be recognised externally by the fact that the entrance doors are flush with the side walls, and the side sheets extended beyond the end walls in a sloping manner giving the vehicle a simple and pleasing streamlined form.

The *Italian State Railways* ordered in 1940 an initial series of 10 main line coaches, type Cz (Fig. 9 and diagram 33), the dead weight amounting to 32 t. (31.494 Engl. tons), a reduction of 10 t. (9.842 Engl. tons) or 24 % on that of the preceding vehicles of the same type. At the present time a further group of 370 similar vehicles is under construction as well as two experimental coaches type ABz. Light alloys are to be used to a considerable extent in both the underframe and body, and this will allow of bringing the tare down to 30 t. (28.526 Engl. tons), which, for an overall length of 23.54 m. ($77'2^{15}/_{16}''$) gives a unit weight of 1 275 kgr./m. (857 lb. per foot). These light weight vehicles, capable of being run at 140 km. (87 miles) per hour, are intended for through trains on the principal routes carrying heavy traffic.

The *North Milan Railway* reports that it has 18 light weight vehicles of the following types :

1. Six motor coaches (voitures-pilote), in special rustless steel, built in 1937, on the American Budd process, weight in working order amounting to 22 t. (21.652 Engl. tons), a saving of 40 %.

2. Six motor coaches (voitures-pilote), in ordinary steel, built in 1942 at the Breda Company's works, and representing a saving of 30 %.

3. Six 3rd class coaches (diagram 36) in ordinary steel, also built by Breda, of 25 t. (24.605 Engl. tons) dead weight for 122 seats, giving a saving of 20 %.

French National Railways.

Fig. 6. — Class B^7 coach before conversion to metal.

Fig. 7. — Class B^7 after conversion to metal.

Hungarian State Railways.

Fig. 8. — Class Cak main line coach.

Italian State Railways.

Fig. 9. — Light-weight coach (1940).

The motor coaches (voitures-pilote), maximum speed 100 km. (62 miles) per hour, are used on the electrified sections, the other coaches on the steam lines where the maximum speed is 80 km. (50 miles) per hour.

The *Netherlands Railways* endeavoured to solve the problem of cutting down the weight by building, prior to the war, a number of motor coach sets made up of several elements which as already stated are beyond the scope of the present report. For international services, the management put into work in 1937 a dozen 3rd class coaches and in 1939 ten others, composite 1st and 2nd class, of all-welded construction, the dead weight of which amounted however to the still fairly high figure of 47 t. (46.257 Engl. tons). The reduction obtained by using electric welding in place of riveting is only about 5 t. (4.921 Engl. tons).

The *Polish State Railways* are building a series of 100 3rd class coaches with side corridors (diagram 37) for the long distance services. Thanks to the wide use of welding in making the principal elements in the vehicle, the dead weight is being got down from 45 to 38 t. (44.289 to 37.399 Engl. tons), a saving of some 15 %.

The *Rumanian Railways* have at present 20 light weight metal vehicles built in 1943, but not put into service until the beginning of 1946 (No. 38, Table I). Their average tare is 28.2 t. (27.753 Engl. tons) or about 16 t. (15.747 Engl. tons) under that of the heavy type metal coaches, a saving of some 36 %. This rolling stock is allocated to the through trains on secondary lines, where the need of limiting the axle loading calls for light weight vehicles. The carrying capacity has in this way been increased by 30 % for the same weight. The appearance of these coaches as well as the tubular form of the underframe body assembly are very similar to those used on the main lines in Sweden.

The *Swedish State Railways*, applying in turn the principle of the tubular girder to the building of metal coaches, have obtained savings in weight from 13 to 17 % according to the type of vehicle, in the case of main line stock, and 20 % in the case of suburban stock. (Nos. 39-53, Table I). Altogether the park of light weight vehicles put into service of recent years totals 284 units, 155 main line and 129 suburban, or 20 % of the passenger bogie stock. The remaining stock consists of 58 % wooden body and 22 % heavy metal vehicles. Diagrams 40, 42, 44, 49 and 53 show the inside arrangement of the principal types of light weight stock. It is to be noted that the width of the underframe-body assembly is 3.134 m. ($10'3^3/_8''$), both for main line and suburban vehicles. It thus exceeds by some 200 mm. ($7^7/_8''$) not only the dimensions currently used in Switzerland and France, for example, but is even 34 mm. ($1^{11}/_{32}''$) wider than the figure met with on the Spanish coaches. Figs. 10 and 11 show the outside of a main line and a suburban coach, of light weight design. The vehicles now being built total 111, divided as shown in Table I.

The privately owned narrow gauge *Stockholm-Roslagen line* has 11 type Co light weight vehicles (Nos. 54 and 55, Table I), of all metal welded construction, weighing some 3 t. (2.952 Engl. tons) or 14 % less than the older wooden-bodied coaches.

In *Switzerland* the use of welding in place of riveting and the partial utilisation of light alloys in the building of the Federal Railways metal vehicles has allowed of reductions in weight, of greater or less consequence. For example, the dead weight of the side corridor coach $AB^{4ü}$ fell from 46 t. (45.273 Engl. tons) in 1933 to 40 t. (39.368 Engl. tons) in 1936, a saving of 13 %. The tare of the latest heavy type vehicles, series $C^{4ü}$ with central corridor, built in 1933, also underwent a small reduction,

Swedish State Railways.

Fig. 10. — Class Co8d main line coach.

Fig. 11. — Class Co6 suburban coach.

less important than that cited above.

It became apparent from that time that appreciable weight reductions could not be obtained short of adopting the tubular form of construction, of which the first applications were made in Europe, notably in France.

It was in 1933 that the Management of the Federal Railways gave the Swiss Coach and Lift Works of Schlieren (known as SWS) working in close collaboration with the Traction and Workshops Department at Berne, the task of designing on the tubular principle a new steel coach, all parts of which were to have their weight systematically cut down. This vehicle was required to give more comfort to passengers, greater protection in case of accidents, and to run more smoothly than the heavy weight stock already in service. In addition, it was stipulated that it was to be capable of being used equally well in fast or through main line services or in stopping suburban trains at the peak hours. The Schlieren Works first produced a prototype of which the under frame-body assembly was subjected in 1934 to static load tests in order to verify experimentally the calculations

made concerning its powers of resistance, and to ascertain which parts of the structure might show signs of having been overloaded. The tests showed that certain parts or places needed strengthening, and various alterations and improvements were introduced, notably in the construction of the assembly itself.

In the spring of 1937, the first 8 light weight steel coaches, two 2nd class, five 3rd class and one buffet car, were put into service in the fast light weight trains running on the Geneva-Zurich line. Fig. 12 shows the outside of the 3rd class coach, notable for its pleasing streamlined outline and slightly tapering ends. Diagrams 56 and 58 give the general layout and arrangement of the inside of coaches types $B^{4\ddot{u}}$ and $C^{4\ddot{u}}$. The buffet car only differs from the 3rd class coach in having the central compartment laid out to take the kitchen, the service room and 20 seat restaurant compartment.

The dead weight of the prototype 3rd class coach was only 25 t. (24.605 Engl. tons) for 72 seats, or a saving in weight of 34 % compared with an ordinary similar coach, the tare of which was 38 t. (37.399 Engl. tons) in 1933. The weight of the first vehicles to be built on production lines has appreciably increased on account of certain improvements introduced into the design; it amounted in the end to 27.1 t. (26.671 Engl. tons) for the $C^{4\ddot{u}}$ vehicles and 27.8 t. (27.360 Engl. tons) for the $B^{4\ddot{u}}$, but still leaves a very appreciable reduction of 28 and 32 % compared with the earlier designs. It is to be noted too that this was got in spite of the fact that the total length was increased of 2.30 m. ($7'6^{9}/_{16}''$), a result of the increased degree of comfort provided for passengers. The weight per unit of total length was in this way reduced, in the case of the 2nd class coach, from 2 000 to 1 220 kgr./m. (1 343 to 820 lb. per foot), a reduction of 39 %.

The following table shows how the dead weight figure is made up in the case of the central corridor $C^{4\ddot{u}}$ all welded steel coaches of the heavy (1933) type and the light (1937) type. In both cases there are 72 seats. The total lengths — over buffers — are 20.4 and 22.7 m. ($66'11^{1}/_{8}''$ and $74'5^{5}/_{8}''$) respectively.

Dead weight of steel coaches type $C^{4\ddot{u}}$.	*Weight in kgr.*		*Savings in weight (kgr.).*
	Heavy (1933) type.	*Light (1937) type.*	
Underframe-body assembly	11 620	9 310	2 310
Buffing and drawgear	1 320	650	670
Brake gear (attached to underframe)	1 060	730	330
Gangways and gangway bellows	300	150	150
Electric heating and lighting equipment	1 500	1 200	300
Internal fittings, lagging and paintwork	10 000	7 830	2 170
Total for assembly	25 800	19 870	5 930 (23 %)
Bogie with dynamo	6 150	3 680	2 470
Bogie without dynamo	5 850	3 550	2 300
Total for bogies	12 000	7 230	4 770 (39.7 %)
Grand totals	37 800	27 100	10 700 (28.4 %)

Swiss Federal Railways.

Fig. 12. — Class C⁴ü light-weight steel coach.

Fig. 13. — Class AB⁴ü light-weight steel coach.

During the last few years the weight of the light steel vehicles has been somewhat increased, as strengthening pieces have been applied to the main framing, as proved by collisions to be necessary, and also to improve the riding qualities. At the present time, the tare figures for the $B^4ü$ and $C^4ü$ coaches amount to 28.8 and 27.9 t. (28.344 and 27.458 Engl. tons), the figures in table I being the average ones.

The Federal Railways have also had built on similar methods luggage vans, some having a post office compartment, so as to combine the two facilities in the one vehicle. In this case the dead weights amount to 22 and 24 t. (21.652 and 23.620 Engl. tons) respectively, these vehicles being also of very light weight design.

During the course of 1944, the light weight steel stock was completed by the putting into service of the following two new types, built on the same lines, and to the same dimensions as the vehicles described above :

1. The side corridor coaches of the $AB^4ü$ and $C^4ü$ types meeting the working conditions laid down by the RIC and intended to cater for the future requirements of international traffic. The arrangement and dimensions of the compartments are given in diagrams 59 and 60. Fig. 13 shows the appearance of the $AB^4ü$ coach, of simple streamlined and pleasant outline. With a deadweight of 28.8 t. (28.344 Engl. tons) for this coach and 29 t. (28.542 Engl. tons) for the $C^4ü$, a reduction in weight of about 28 % is obtained compared with the designs, already somewhat lightened, of the 1936-1938 period, in spite of an increase in overall length of 1.30 m. (4′ $3^3/_{16}$″), with the same number of seats. It is to be noted that these new coaches do not yet carry the RIC distinguishing sign, as they have electric heating at 1 000 volts, 16 $^2/_3$ cycles, and consequently they are being used for the time being in through internal services. Steam heating would add about 1 t. to the weight.

2. The steel restaurant car, shown in Fig. 14, intended to supplant the buffet cars on the light fast trains, the latter vehicles having proved insufficient to meet requirements, owing to the increasing number of passengers wishing to take full ordinary meals. Diagram 61 shows the layout of the coaches, the dining compartment, service room and kitchen, etc. The entire kitchen equipment, including the large cold storage cupboard, is electrical, power being furnished by two transformers, either from the general heating circuit or direct from the contact wire by a pantograph of normal design on the coach roof.

The dead weight of this vehicle is 32.4 t. (31.887 Engl. tons), while that of the latest types of the Swiss Restaurant Car Co., built in 1930, is 48 t. (47.241 Engl. tons) for the same number of seats; this gives therefore a considerable saving, amounting to 15.6 t. (15.353 Engl. tons) or 32.5 % although the total length has been increased by 2.30 m. (7′$6^9/_{16}$″) providing more space per seat and less cramped service compartments.

At the end of 1946, the number of light steel vehicles built for the Federal Railways by the two firms, that at Schlieren already mentioned, and the Swiss Industrial Company at Neuhausen (SIG) amounted to 179, namely: 117 passenger coaches, 5 buffet cars, 10 restaurant cars and 47 luggage vans, 8 with postal accommodation. At the moment 59 others of various types are being built by the concerns just mentioned.

The electrification of the Brünig line, at the outbreak of the war, raised the problem of how to construct new passenger coaches capable of meeting the new operating conditions, namely raising both the maximum and average speeds and the number of trains consequent of the new method of traction. The line is of narrow gauge, 1 m. (3′$3^3/_8$″), 74 km. (46 miles) long, connecting Lucerne with Interlaken, via the Brünig pass, 1 002 m. (3 287′) above sea level. The route profile contains two sections worked by adhesion in the valleys, with maximum gradients of 18 $^0/_{00}$, separated by a 15 km. (9.320 miles) rack rail section with gradients

Swiss Federal Railways.

Fig. 14. — Class Dr'ü light-weight steel restaurant car.

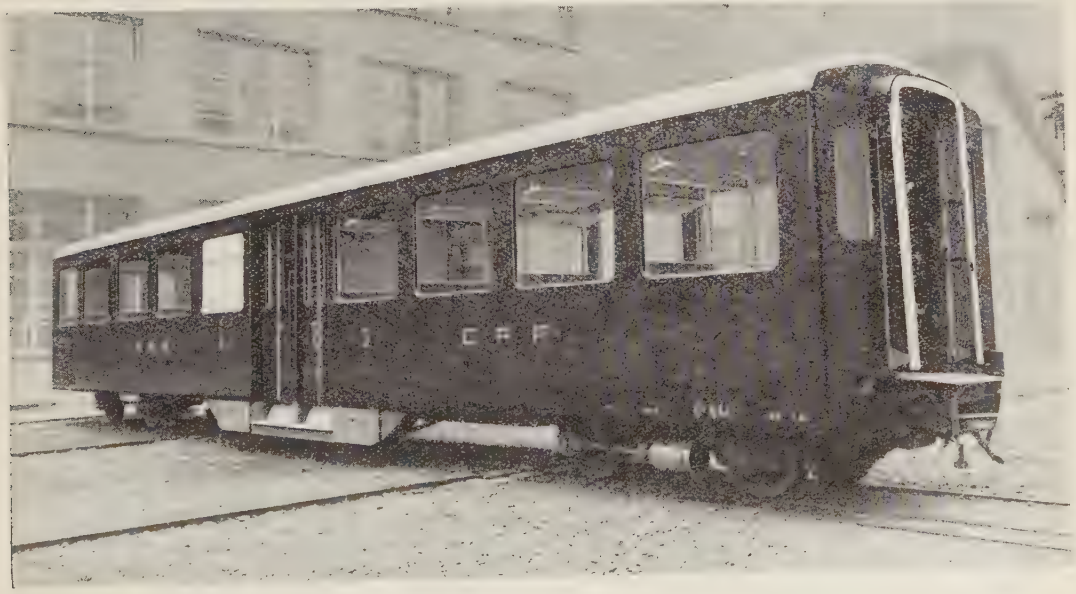


Fig. 15. — Class C⁴ü light-weight coach for the Brünig line.

on each side at the approach to the summit of 120 ‰. The motor coaches can haul 240 t. (236 Engl. tons) trains on the adhesion sections at a maximum speed of 75 km. (47 miles)/h., and 60 t. (59 Engl. tons) trains at 30 km. (19 miles)/h. on the rack sections. Owing to the increase that has taken place in the traffic many trains must afford 200 to 250 seats, which, with the existing stock, gives a weight of 74 t. (72.831 Engl. tons) and requires the use of two motor coaches.

Nearly half the passenger rolling stock is made up of 6-wheeled coaches which have largely passed their useful life and are unfitted to run at the speeds met with on electrified lines. Although the latest bogie coaches built are in fact of light weight design (wooden body covered with aluminium sheet), it was seen to be essential to effect a further important reduction in weight to avoid having to use two motor coaches to a train. The designing of the new vehicles was entrusted to the « Société Industrielle Suisse » at Neuhausen and 27 in all were ordered in 1942 and 1943 (Nos. 62-64, Table I).

In view of the excellent results obtained with light weight steel vehicles, the design used with them was taken as the basis on which to work; but in order to obtain the greatest possible saving in weight and take account of the shortage of steel then obtaining, it was decided to employ aluminium alloys for all the elements of the body framing except the headstocks, which are of welded steel plate.

Fig. 15 is a view of the 3rd class coach, notable for its simple outline, the central position of the doors and the large size of windows. The first eight coaches were put into service in 1945. It had been hoped to get a tare figure of not more than 11 t. (10.826 Engl. tons) for the $C^{4ü}$ coach, but in actual practice it amounted to 12.6 t. (12.4 Engl. tons), giving therefore a saving of 19 % over earlier designs in spite of an increase in overall length of 2 m. (6′6¾″). The weight per unit of overall length is 765 kgr./m. (515 lb. per foot) against 1 060 kgr./m. (712 lb. per foot), giving a very important reduction of some 28 %. The increase in dead weight over what was intended when getting out the design resulted from various improvements introduced during manufacture, such as better brake gear — 8 brake blocks per axle instead of 4 — the use of separate brakes for adhesion working and rack working, and the fitting of flexible gangway-bellows. In addition, the plates used to cover the framing, on account of their large size, could not be supplied in the desired gauge, and had to be some tenths of a millimetre stouter. The girder framed body of the first coach was subjected to thorough static load tests, which will be referred to in detail in the next chapter.

The Federal Railways still have a very important group of 4 and 6 wheeled coaches, making up about 2/3 of the effective park, the comfort offered by which leaves much to be desired. They are becoming more and more the subject of criticisms on the part of passengers, especially since the light weight steel coaches appeared. For some years the management has been faced with the problem of how either to scrap these vehicles and replace them with modern designs, or to convert them into bogie stock with new metal bodies. For financial reasons, and also on account of prevailing industrial conditions, it has not been possible to adopt the policy of scrapping. It has therefore been decided to make a trial of converting in the manner stated, the new body being built up entirely in light alloys and mounted on the old steel underframe with its two tie rods. In all 11 trial vehicles are under construction, 5 of the BCF^4 type with lug-

gage compartment, to act as trailers to the electric motor coaches, and 6 coaches of the BC^4 and C^4 type for service on the secondary lines with steep gradients (Nos. 65 to 67, Table I). The expected dead weights will be 21 t. (20.668 Engl. tons) for the BCF^4 and 19 t. (18.699 Engl. tons) for the C^4, which, in the latter case, will give a weight per seat of only 297 kgr. (655 lb.), and one per metre of overall length of 1 030 kgr. (692 lb. per foot). The small saving in weight obtained compared with a tubular type steel design is due to the fact that the body in light metals does not play a part in the resistance offered by the assembly. Nevertheless, this new design is worthy of some notice here, for it represents the first application in Switzerland of light metals in the building of the body framing of standard gauge coaches. The experience obtained in service will be extremely useful to builders and managements alike in arriving at the behaviour of light alloys in rolling stock construction, a field in which as yet experimental results do not amount to much.

The Swiss privately owned railways have also put into service of recent years a certain number of light weight vehicles built on the pattern of those of the Federal Railways by the Schlieren and Neuhausen works. We give the most important of these in the table I (Nos. 68 to 73), namely those of the Berne-Loetschberg-Simplon (Fig. 16), the Swiss South-Eastern (Fig. 17), the Rhaetian Railways (Fig. 18) and Montreux-Bernese Oberland (diagram 72).

The *Turkish State Railways* have also endeavoured to cut down the weight of the rolling stock, without, however, giving preference to very light designs or the use of light weight materials, so as not to reduce the factor of safety in operation. In replacing steel sections by bent or stamped platework and using welding for all the assemblies in the underframe body and roof, they have nevertheless succeeded in obtaining a substantial reduction in weight, amounting for example to 16.5 % for the coach series AB^4, the dead weight of which fell from 44.9 to 37.5 t. (44.190 to 36.907 Engl. tons). These are the only particulars we obtained from this administration.

The *Jugoslavian State Railways*, owing to the difficulties now facing their heavy industries, which are unable to supply complete bogies, have decided to convert to metal construction 200 bogie coaches, replacing the wooden body by metal framing. This is now being done on a first group of fifty 3rd class coaches (diagram 74) intended to run in main line expresses. The dead weight varies from 32 to 35 t. (31.494 to 34.447 Engl. tons), according to the existing types of bogies, but this nevertheless respresents a saving in weight of some 20 % compared with wooden bodied coaches, and 30 % in the case of the heavy metal type vehicles.

The *International Sleeping Car Company* has given us details of 4 sleeping cars, built in 1939, but requisitioned by the Germans immediately on their appearance in service in 1942. These vehicles, which have disappeared in the course of military operations, were prototypes from the point of view of weight reduction, heating by warmed air, streamlined shape of body and the brake equipment. They were 23.45 m. ($76^1\ 10^{15}/_{16}$") long overall, with 22 berths. The tare figure was 48 t. (47.241 Engl. tons), a saving of 5 t. (4.921 Engl. tons) only over previous designs. They were suitable for speeds up to 165 km. (102 miles) per hour.

* * *

Fig. 16. — Class C^4 light-weight steel coach.

South-Eastern Railway (Switzerland).

Fig. 17. — Class $C^4ü$ light-weight steel coach.

Rhaetian Railways (Switzerland).

Fig. 18. — Class $C^4ü$ light-weight steel coach.

In our questionnaire, we asked the various managements to state what they considered to be the lowest limit of dead weight attainable in a coach, without any lowering of the standards of smooth running, comfort, and safety at present accepted. The French National Railways consider that short of resorting to the use of special steels or light alloys in constructing the principal parts of the underframe and body, it is not possible to bring down the dead weight below 30 t. (29.526 Engl. tons) for main line vehicles of this type, without altering their high resistance to shock and hence the standard of safety. They state on the other hand that reducing the weight has no noticeable effect on comfort if care is taken to use a sufficiently flexible system of spring suspension and a suitable degree of sound and temperature insulation.

The Swiss Federal Railways fix the limiting figure at 25 t. (24.605 Engl. tons) for their light weight steel coaches. They point out that only a framing made entirely in light metal could bring a further appreciable reduction in weight, but that the two chief obstacles in the way of doing this are the difficulties encountered in uniting the various components and the high first cost of the materials.

The Italian State Railways adopt a figure of 30 t., the Polish State Railway 33 to 34 t. (32.478 to 33.463 Engl. tons), the Rumanian 28 t. (27.557 Engl. tons), and the Jugoslavian State lines 31-34 t. (30.510 to 33.463 Engl. tons) as the minimum weight allowable in their light weight rolling stock, maintaining the same standards of comfort and safety. The Belgian Railways consider that the question is one to be settled by experience and contemplate making trials of behaviour in service under an overload of 80 % with the light weight vehicles now being designed.

It seems clear from the above that the French coaches, both main line and branch, and the light weight Swiss vehicles represent the lightest type of stock that can be considered practicable in the existing state of technical development, without incurring a diminution in the standards of comfort and safety attained hitherto.

Finally we may draw attention to a project now being work out by the Michelin Company for a set of six vehicles running on pneumatic tyres, with a probable dead weight of 16 to 18 t. (15.747 to 17.715 Engl. tons), capable of being constructed either in stainless steel, ordinary steel or light alloys. The use of pneumatic tyres puts the question of comfort and of the stresses affecting the underframe and body under an entirely different angle from that involved with vehicles of classic design, running on two hard surfaces in contact. This is perhaps the direction in which future designs will tend to develop in an endeavour to obtain a further saving in weight.

Regarding the effect of weight reduction on costs of haulage, most Administrations have supplied no precise information. The Italian State Railways admit that these costs fall by an amount equal to the percentage of weight reduction achieved multiplied by a co-efficient varying between 0.25 and 0.35, the first figure relating to steam, the second to electric trains. The French National Railways consider that for a 15 coach train of 32 to 34 t. tare per coach, the average reduction in dead weight of 180 t. (177.157 Engl. tons) or 27 %, will cut running costs by 10 % ,i.e. by about a third of the percentage of weight reduction. Generally speaking, this gain is absorbed by a corresponding increase in the speed and consequently a reduction in running time. This amounts to saying that the carrying capacity of a train can be appreciably increased without any additional operating costs being incurred. Weight reduction also

offers certain other definite advantages, not easily expressed in figures :

— the appreciable saving in the amount of material consumed in building a vehicle;

— the reduction in track maintenance costs as a result of the smaller axle loads;

— the possibility that the trains may in due course be hauled by less powerful and therefore lighter engines, costing less to build and causing less wear and tear on the permanent way.

On the Swiss Federal Railways this last named advantage has received practical expression by the building of a new and very light electric locomotive, type Bo-Bo, weighing only 56 t. (55.115 Engl. tons) in working order (or 14 t. per axle [13.178 Engl. tons]) which will allow it to take curves 10 km. (6 miles) /h. faster than the existing locomotives. This engine, the first deliveries of which were put into service in 1946, is used to haul fast trains composed of light weight steel vehicles; in this way quite clearly every possible benefit due to weight reduction can be taken advantage of.

As regards first costs, these are of course in some degree increased by the process of weight reduction. This results from the use of materials of greater specific cost (special steels and light alloys) and the higher costs occasioned by skilled labour in manufacture, for example in welding. The French National Railways consider that this increase will not exceed a priori 5 % of the total cost. The Swiss Federal Railways give a figure of 25 % as the increase in manufacturing cost for its light weight stock, compared with the heavy steel type. It should be noted, however, that this is not entirely attributable to the cutting down of the weight; it is due also to the numerous improvements effected in the design, for the purpose of reducing upkeep costs and adding to the passengers' comfort.

The purchase price of the light weight coaches for the Brünig line was increased by some 25 % by the extensive use of light alloys.

Finally the effects of weight reduction are almost nil on maintenance charges and the life of the stock, the latter having to be at least equal to that of the heavy metal designs.

* * *

II. Construction of the underframe-body assembly.

The metal skeleton or framing of the underframe-body assembly is one of the essential items in which, up to the present, the most important reductions in weight have been made.

The greater number of the vehicles referred to in the preceding chapter are of the tubular girder type in which the three principal components, underframe, side walls and roof are united in such a manner as to form as homogeneous an assembly as possible. This tubular girder may be, in a general way, defined as follows : — the outer shell of the tube is made up of the plating which covers the floor, the sides and the roof, forming a cross section substantially rectangular in shape with rounded corners. The tube is hooped internally by a series of transverse rings, each continuous and complete in itself, located between two bays, and made up of a cross member of the underframe, a vertical member or body post, and a roof rib. These rings are supported by the outer sole bars of the underframe on the one hand, and the roof sheets on the other. Transverse and longitudinal strengthening pieces, made up of portions of the rings and of longitudinal sills are provided for the purpose of reducing the amount of unsupported surface in the sheathing, and hence the risk of the plating being torn away or

the buckling of any part of the assembly. To complete the whole, the tube is closed at the ends by stout walls united solidly to the underframe and roof by box gussets or bracing, forming shock absorbers capable of taking up elastically a very considerable amount of stress. In this design the assembly made up of the underframe, sides and roof provides the strength needed to resist bending and compression by making use of the maximum moment of inertia obtained from the tubular character of the girder so formed, the nearest obtainable to a tube of circular cross section, the ideal resisting member. In this way we obtain with the minimum amount of material an assembly formed of the underframe and body endowed with the greatest power of resistance not only to normal vertical loads but to accidental stresses acting on the ends. It is by bringing a judicious choice to bear on the methods of construction and the materials used that we obtain the maximum amount of reduction in weight in this portion of a coach without altering for the worse its powers of resistance.

We will consider first of all the steel skeleton or framing used in the French, Italian, Swedish and Swiss vehicles cross sections of which are given in Figs. 19 to 23, with some part longitudinal sections, showing the rings used for hooping the structure internally. From these drawings it can be seen at once that the assemblies of the French, Swedish, and Swiss coaches conform completely to the tubular idea, as we have just described it. On the other hand, that of the Italian coaches is of semi-tubular form, in which the resisting power is localised almost entirely in the underframe and the side wall bracings, the walls themselves being simply rivetted to the underframe sole bars. It is to be noted too that in this design, there is a want of continuity in the hooping rings. The principal function of the roof is to unite as rigidly as possible the two faces of the upper portions of the walls.

In France, the light weight 1936 suburban coaches maintained the tubular form of assembly in principle identical with that designed in 1929 by the drawing office of the old French Est Company, in which, however, ordinary mild steel was replaced by a semi-hard steel offering a minimum tensile figure of 60 kgr./mm² (38.09 Engl. tons per square inch.) and rivetted seams replaced by electric arc or resistance welding. In this way a considerable reduction in weight of some 3 100 kgr. (6 834 lb.) was obtained in the steel required for the new framing. These arrangements, applied in due course to the main line coaches, type C11 of 1938, have proved their worth in all the metal type rolling stock built by the Est Company. The French National Railways have taken them up again in designing the underframe-body assembly of its new stock, taking advantage also of course of technical progress since achieved, notably in welding processes, and the experience gained by the largest industrial concerns engaged in this work.

It will be noted from Figs. 19, 20 and 23 that in this type of construction, the underframe is brought within the body and the body is overlapped by the roof, uniting the three in solid fashion, and maintaining the continuity of the internal hooping. In the French and Swiss coaches particularly, the broad shape of the cross members of the underframe and the roof ribs is to be noted, these items being so constructed as to possess a high moment of inertia, with large perforations to keep the weight down.

Generally speaking, the most important reinforcing members are to be found in the roof of a coach, on account of the small thickness of the sheeting, which is 1.5 mm. (0.059 inch.) in the majority of tubular designs, and the fact

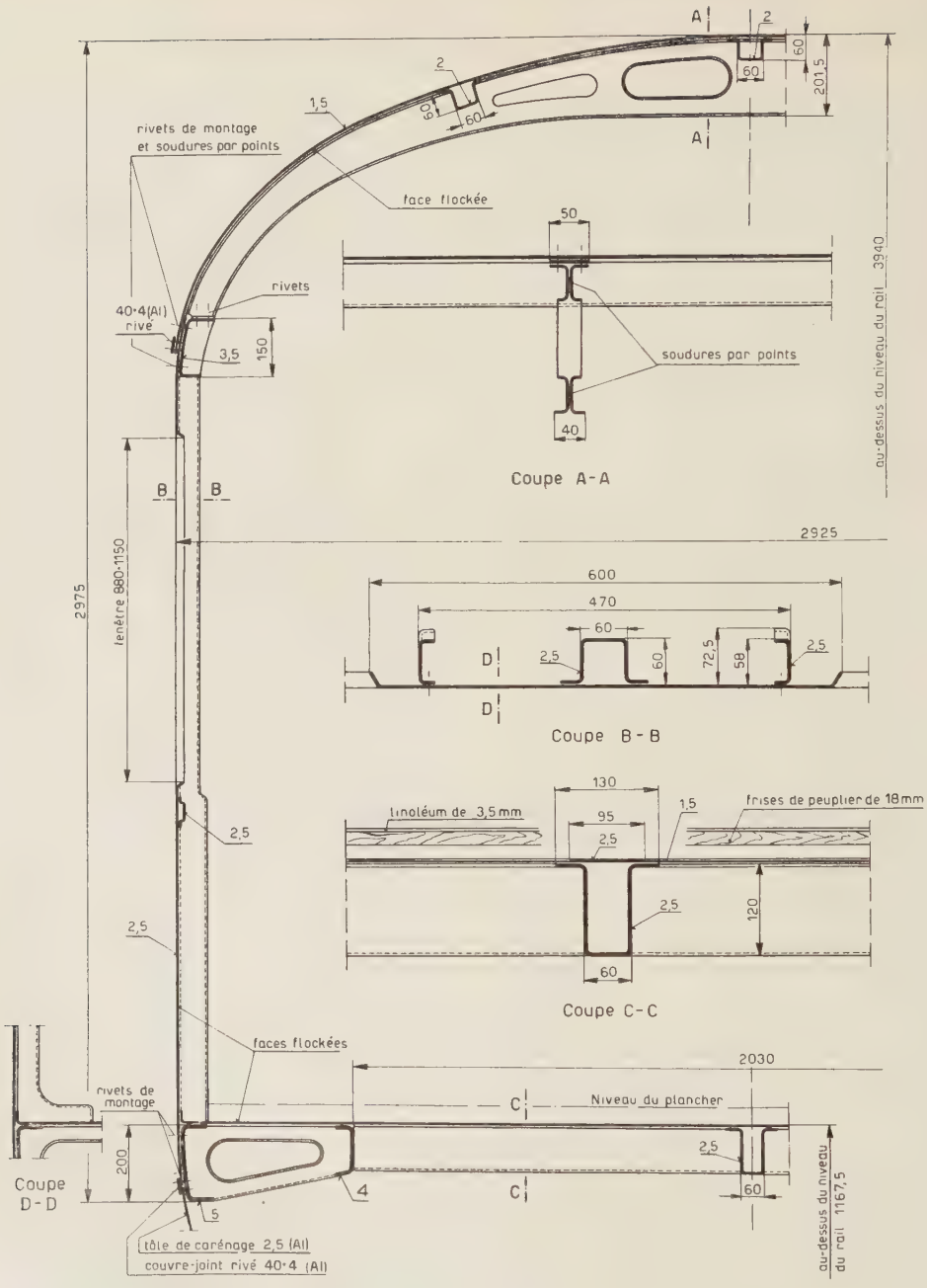


Fig. 19. — Cross section of the underframe-body assembly of a streamlined main line coach.

Explanation of French terms :

Rivets de montage et soudure par points = Rivets and electric spot welding. — Rivets = Rivets. — Rivé = Rivetted. — Face flockée = Flock lining. — Coupe... = Section through... — Au-dessus du niveau du rail = Above rail level. — Fenêtre = Window. — Linoléum de 3.5 mm. = 3.5 mm. linoleum. — Frises de peuplier de 18 mm. = 18 mm. (45/64") poplar flooring. — Niveau du plancher = Floor level. — Tôle de carénage = Streamlined casing. — Couvre-joint rivé = Rivetted junction plate.

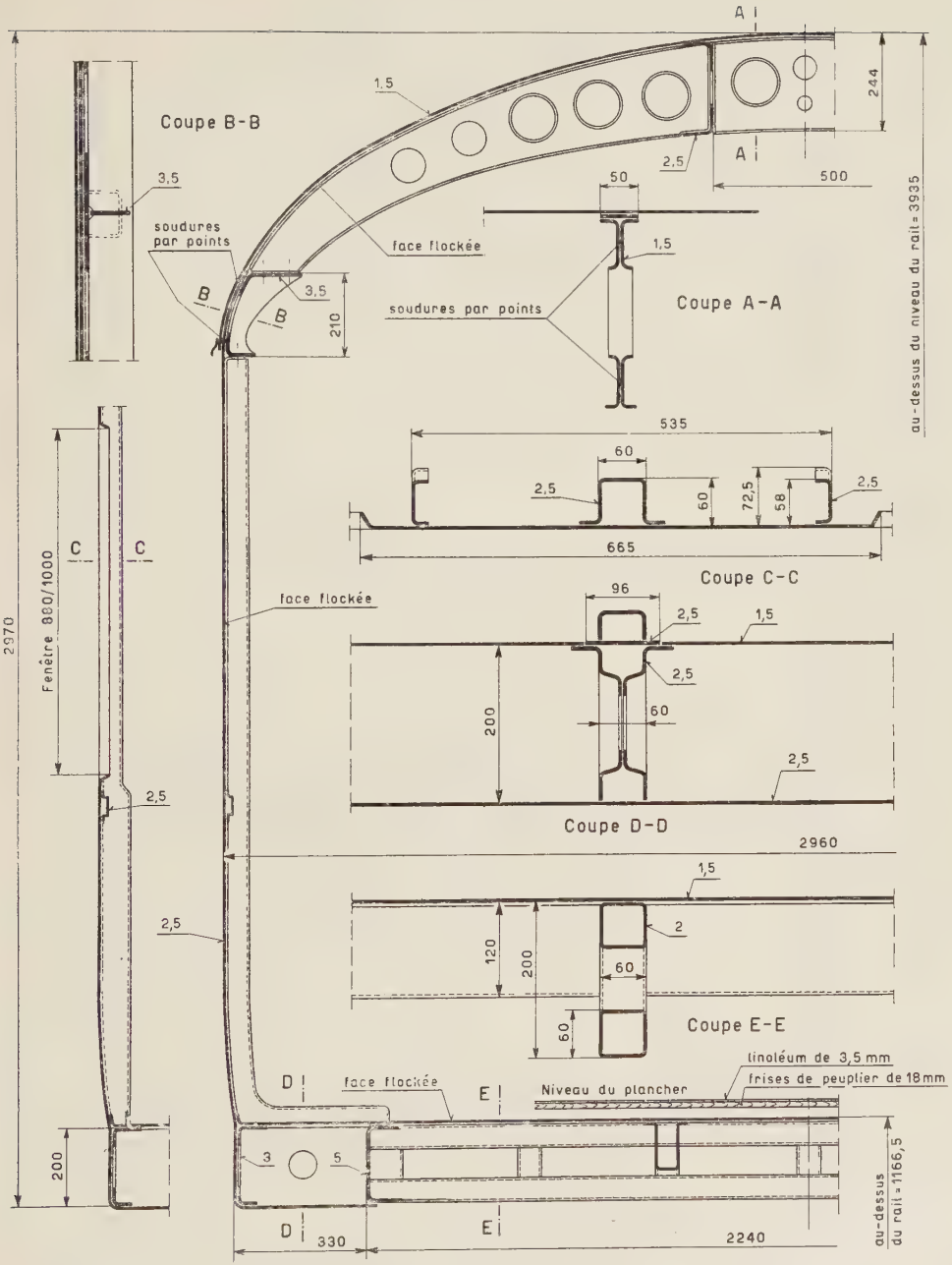


Fig. 20. — Cross section of the underframe-body assembly of a branch line coach.

Explanation of French terms :

Coupe = Section through. — Soudures par points = Electric spot welding. — Face flockée = Flock lining. — Au-dessus du niveau du rail = Above rail level. — Fenêtre = Window. — Niveau du plancher = Floor level. — Linoleum de 3.5 mm. = 3.5 mm. linoleum. — Frises de peuplier de 18 mm. = 18 mm. poplar flooring.

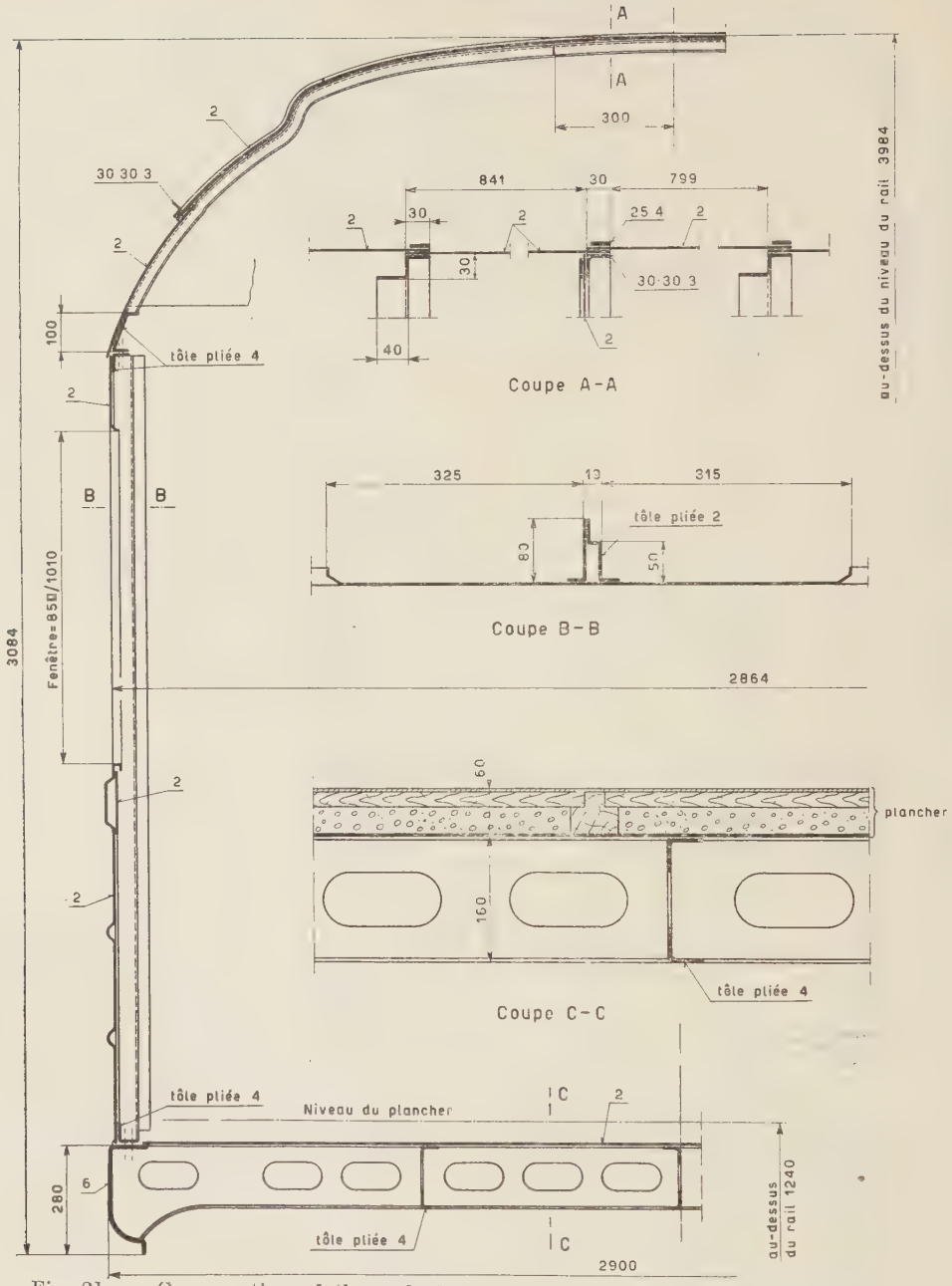


Fig. 21. — Cross section of the underframe-body assembly of a light-weight coach.

Explanation of French terms :

Au-dessus du niveau du rail = Above rail level. — Fenêtre = Window. — Coupe... = Section through... — Tôle pliée = Bent plate. — Plancher = Floor. — Niveau du plancher = Floor level.

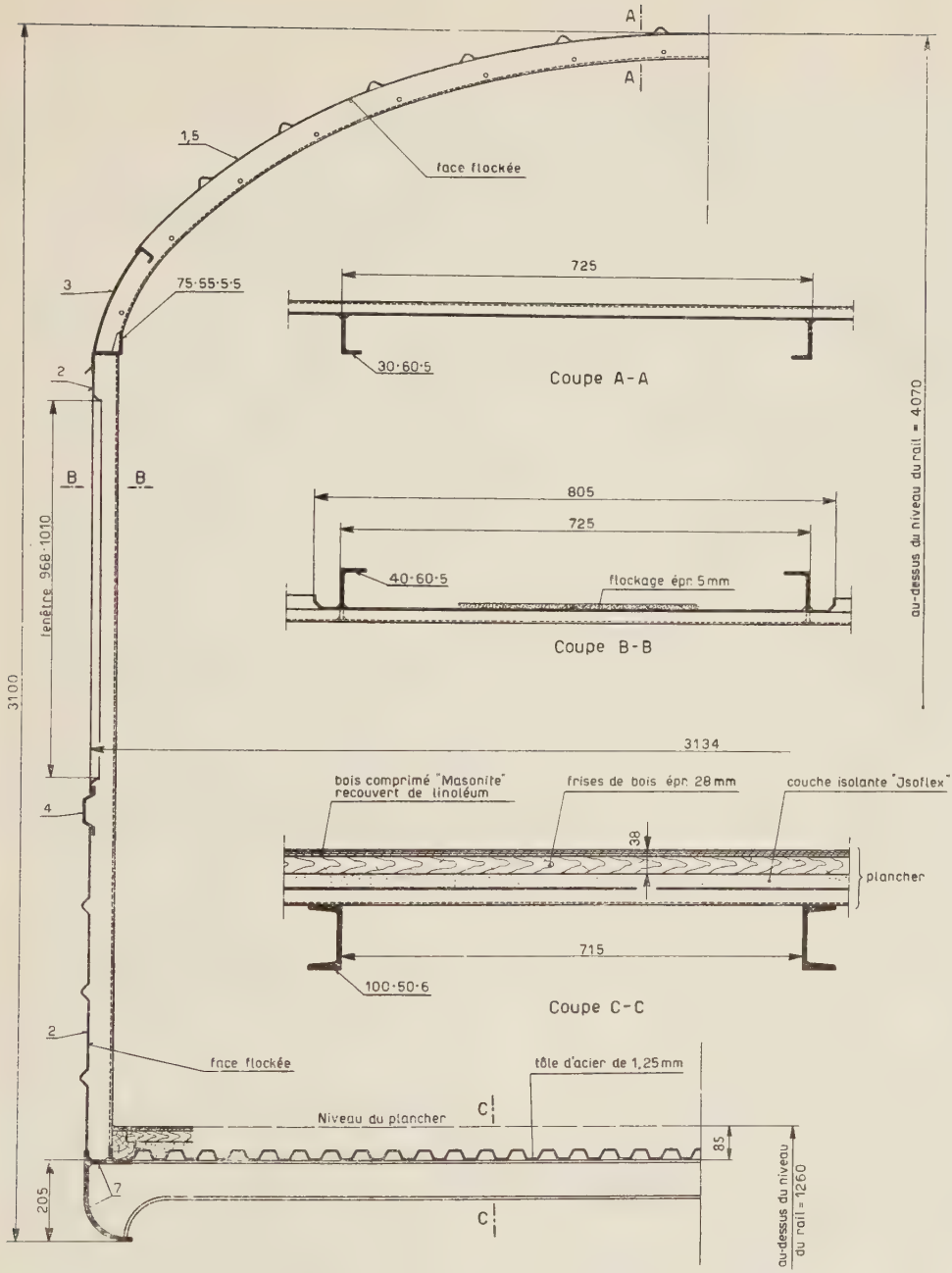


Fig. 22. — Cross section of the underframe-body assembly of a light-weight coach.

Explanation of French terms :

Coupe = Section through... — Fenêtre = Window. — Face flockée = Flock lining. — Flockage épr. 5 mm. = 5 mm. thick flock lining. — Au-dessus du niveau du rail = Above rail level. — Bois comprimé... linoléum = « Masonite » compressed wood covered with linoleum. — Frises de bois épr. 28 mm. = 28 mm. thick wood flooring. — Couche isolante « Osoflex » = « Osoflex » insulating material. — Plancher = Floor. — Niveau du plancher = Floor level. — Tôle d'acier de 1.25 mm. = 1.25 mm. (0.0492 inch.) thick steel plate.

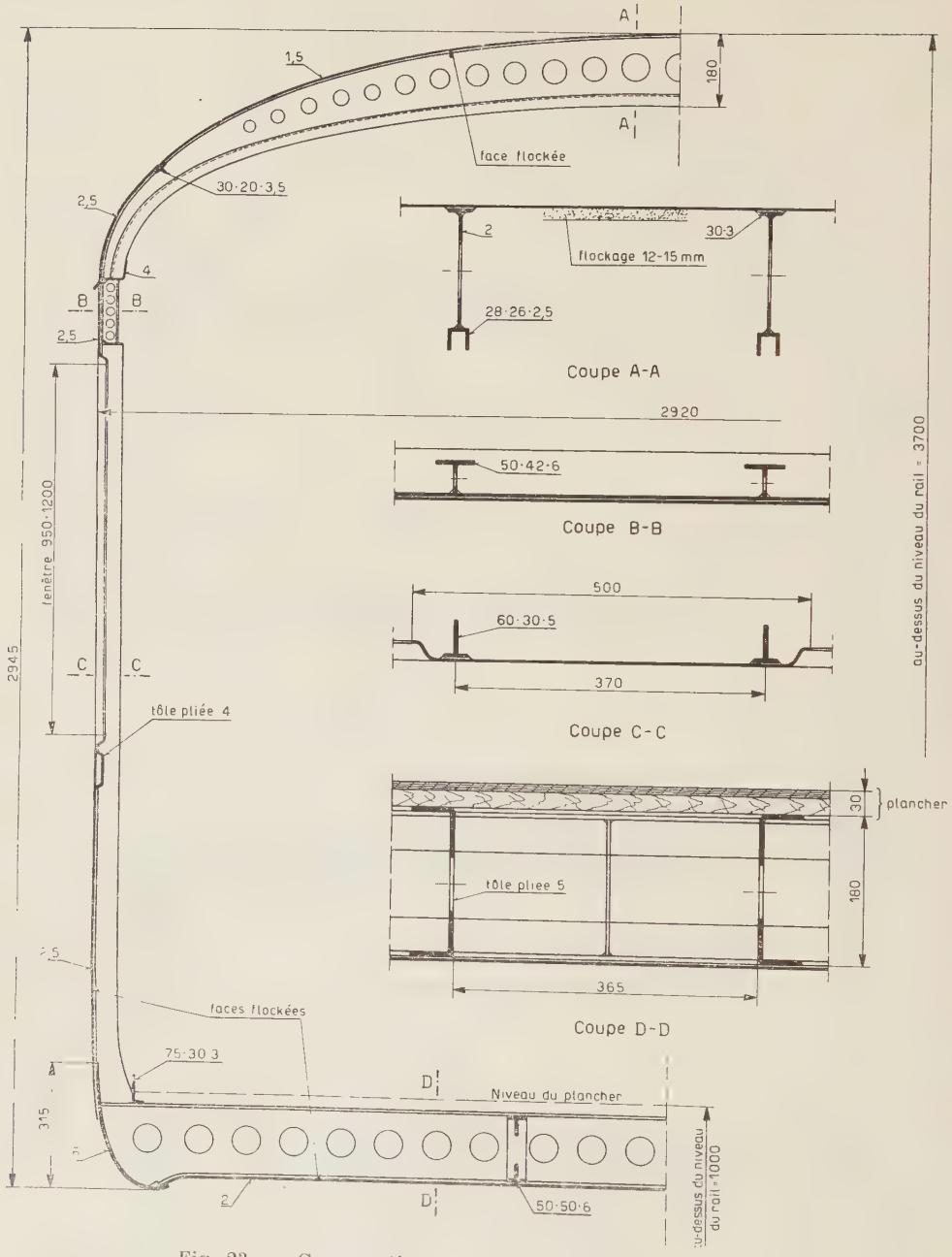


Fig. 23. — Cross section of the framework-body assembly of a class C⁴ü light-weight steel coach.

Explanation of French terms :

Face flockée = Flock lining. — Coupe... = Section through... — Fenêtre = Window. — Au-dessus du niveau du rail = Above rail level. — Tôle pliée = Bent plate. — Plancher = Floor. — Niveau du plancher = Floor level.

that we are there concerned with the portion of the girder formed by the body which is subjected to compression by bending. In addition, the roof is subjected to the intense heat of the sun's rays in summer and to cold in winter, so that the variations of temperature in this part of the vehicle are particularly great. As principal reinforcing elements we have first of all the supplementary roof ribs situated above the bays. There are almost always two, formed by bent plates or light Z, U or L sections. The French National Railways coaches, especially the suburban coaches, are those which have the greatest number of longitudinal stiffeners. In the light steel Swiss Federal Railways coaches there is between the roof properly so called and the sheating an intermediate and thicker piece of plating, welded end to end, with the roof plate carried on a T iron forming the sole longitudinal strengthening member. The Swedish coaches are built similarly.

Generally speaking, we may say that compared with the designs of 1933, there has been a noticeable progressive reduction in the thickness of sheathing plates, which now measure from 1.5 to 2.5 mm. (0.059 to 0.0984 inch.), while laminated sections are being more and more replaced by bent up or stamped sheets, enabling one in each case to arrive at the section affording the maximum resistance from the minimum amount of material. Profile sections have been got rid of altogether in the framework of the French National Railway coaches, while in the Swedish ones, only the underframe longitudinals are in bent platework. In the latter coaches, the sheets used in the walls and roof have longitudinal ribs which allow of their thickness being somewhat reduced or, in the case of the roof, to increase the rigidity without having to use extra parts. In the French and Swiss coaches an attempt has been made to get the outside surfaces as smooth as possible to reduce air resistance and facilitate cleaning. The new French main line coaches and those of the FS and MAV have the ends of the body extended in streamlined form, in such a way as to reduce the free space between two coaches coupled together, a point where the eddy currents of air are particularly harmful at very high speeds. In addition, on the French coaches the side sheets are extended at the bottom by streamlined aluminium sheeting.

As regards materials, ordinary mild steel of tensile strength of 37 to 42 kgr./mm² (23.49 to 26.67 Engl. tons per sq. inch) is the most widely used on account of the ease with which it can be welded and its reasonable price. The French National Railways employ for the framework of their new coaches a semi-hard steel of 65 kgr./mm² (41.27 Engl. tons per sq. inch) tensile with elastic limit of 40 kgr./mm² (25.40 Engl. tons per sq. inch) and 20 % elongation. The Italian State Railways are using a steel of a quality intermediate between the two.

In all the frameworks we have considered, electric arc welding is now commonly used in completing the assemblies. Resistance welding is also used to a considerable extent, especially on the French National Railways. The Italian State Railways generally use autogenous welding in assembling the items forming the underframe and the side sheets. The roof on the other hand, is rivetted. Particular attention is devoted to the means of uniting the principal parts of the framework, that is to say the underframe and the body on the one hand and the body and the roof on the other. By way of example, the extreme solidity of the points of connection on the roof plates of the new French National Railways coaches may be cited, the side sheeting and then that of the roofing, bearing against them and being welded thereto.

French National Railways.

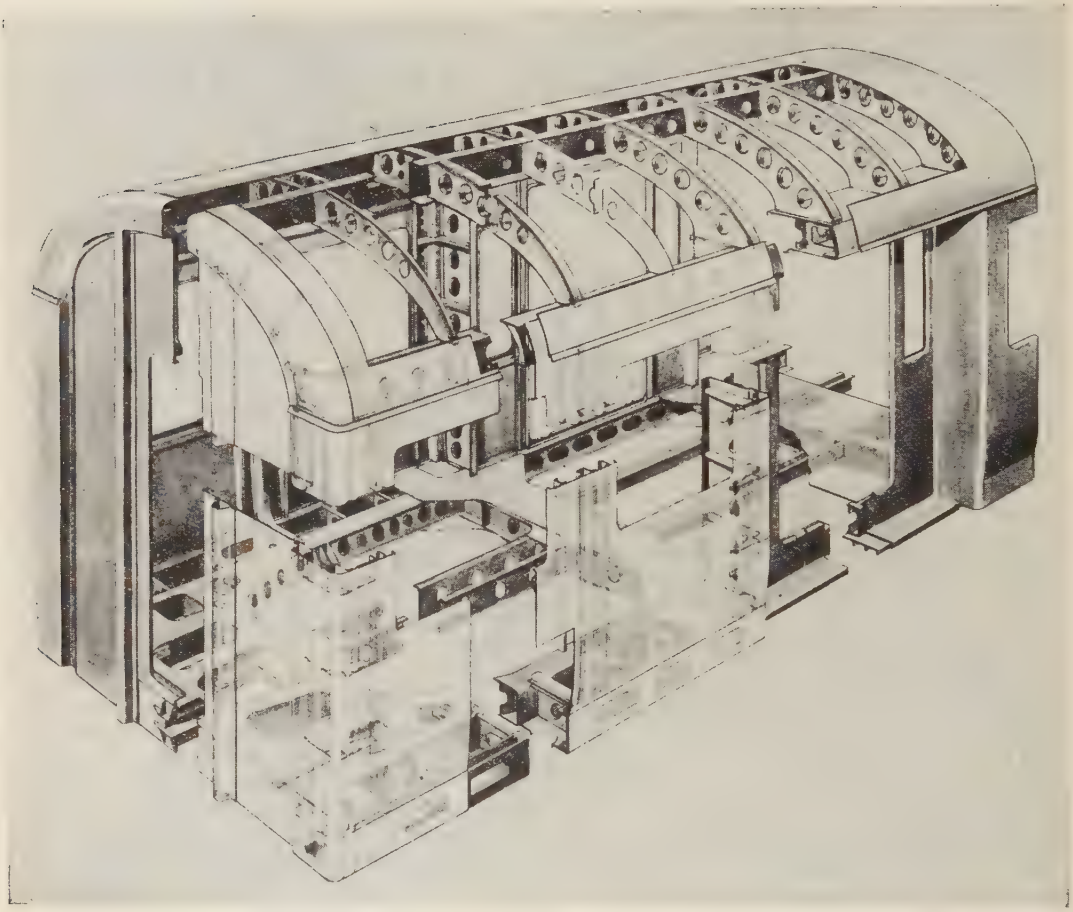


Fig. 24. — End view of the framework of a branch line coach.

Fig. 24 gives a perspective view of the end of the underframe and body assembly of the French National Railways branch line coaches, where the development of the ends of the underframe and strengthening members of the end walls are to be noted as having been provided to resist effectively any accidental shocks. Fig. 25 shows the framework of a Swiss Federal Railways light steel coach, series AB^{4}ü, before receiving the roof.

As another example of the tubular type of construction, we will mention the streamlined coaches of the former French State Railways, the first of which were put into service in 1936. They offer some interesting features, worth noting, in comparison with the classic types of such designs considered

Swiss Federal Railways.

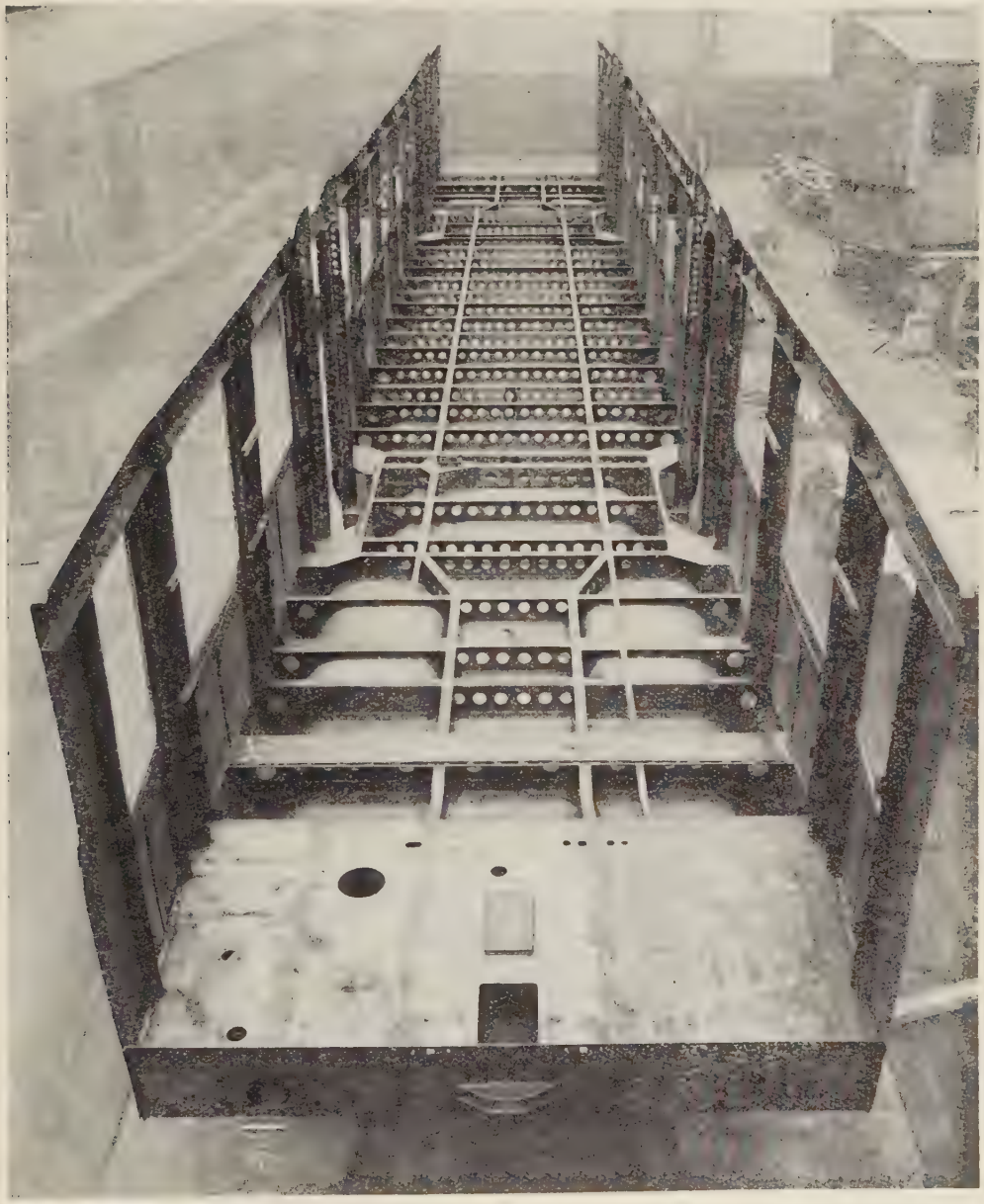


Fig. 25. — Framework of a light-weight Class AB^{4}ü steel coach.

above. First of all, the tubular girder is of oval section, adopted with the intention of approximating towards the ideal section and conforming to aerodynamic principles. The shell of this girder is made up of the normal components, longitudinals, roof sheets and hooping rings, formed of bent or stamped plate. The internal staying of the tube is provided by the underframe support for the floor, made as a horizontal lattice girder. A series of vertical lattice girders completes this staying and supports the lower portion of the streamlining. The outside panelling of the tube is formed of plates 1.5 mm. thick. All essential parts of the structure are in 65 kgr./mm² tensile steel, electrically welded together. The one shell body so obtained weighs 14 900 kgr. (14.663 Engl. tons), a high figure compared with that of the Est Railways light-weight stock.

We have grouped together in the following table a few details concerning the steel frameworks which we have just considered.

Country.	*Type of coach.*	*Dead weight. Tonnes.*	*Underframe-body assembly.*			
			Length. m.	*Weight.*		
				total t.	*unit kgr./m.*	*% of dead weight.*
France.	Main lines C^{10} (1946) . .	32	22.286	8.1	364	25.3
	Branch line (1946) . . .	29	20.500	9.2	450	31.7
Italy.	Cz (1940)	32	21.350	7.4	347	23.1
Sweden.	Main lines	39	22.200	9.5	428	24.4
	Suburban	30.9	20.930	7.5	358	24.2
Switzerland.	$C^4ü$ (centre corridor) . .	27.1	21.400	9.3	435	34.3
	$AB^4ü$ (side corridor) . . .	28.8	21.400	11.0	515	38.2

The reductions in weight that have been obtained are of the order of 15 % for the French C^{10} coaches, 30 % for the Swedish and 20 % and 17 % respectively for the Swiss $C^4ü$ and $AB^4ü$ vehicles.

This table makes it clear that the weight of the framework of the underframe-body assembly accounts for no more than a quarter or one third of the total dead weight, according to whether the process of lightening has been applied to some parts only, or to all parts of the vehicle. It is obvious that a comparison of the weights shown above can have only a relative value, seeing that the resistance offered by the various designs to dynamic effects is certainly not the same in all and cannot be arrived at by calculation. We may point out that on the French branch line vehicles and the Swiss light steel ones, the large openings formed in the side sheets of the body for the doors necessitate special strengthening pieces being applied at these points, to maintain continuity of structure and hence the resistance of the whole. As can be seen from the figures in the last column but one, the unitary weight of the framework of these coaches is on this account

greater than in the case of those in which the entrance doors are at the ends.

In all the types of construction so far dealt with, there is not one using special high tensile steel. The use of chrome-nickel steel (18-8) made by the American Budd process has been applied only to the double railcars of the former French State system and six motor coaches (voitures-pilote) of the North Milan Railway.

We now turn to the consideration of special designs of underframe-body assemblies constructed of light alloys. The first to be dealt with are the three prototype vehicles forming the articulated set built in 1934 in the French Nord Company's shops. It is a mixed design, comprising a steel underframe of lattice girder form, capable itself of withstanding all the stresses arising in service, surmounted by a body or streamlined casing in light alloy. The latter, of tubular form, is formed by two side sheets of 3.2 mm. ($^1/_8$″) thickness, which extend to the roof longitudinals. The roof is reduced to a central band or strip 1 700 mm. (5′6$^7/_8$″) wide, riveted in position after the two side sheets have been erected on the underframe. The metal used is an aluminium alloy called « duralinox » containing 7 % of magnesium. The weight of the body of an end coach of the set, 20 m. (65′7$^3/_8$″) long is of the order of 3.6 t. (3.542 Engl. tons), and that of the underframe 7 tonnes (6.889 Engl. tons). Compared with the steel vehicles of similar date, the reduction in weight attained in the body alone is about 34 %; the weight of the underframe has remained about the same.

The framework of the underframe-body assembly of the light weight Brünig (Switzerland) line coaches of which Fig. 26 gives a cross section, is formed entirely in aluminium alloys, except the headstock and the centre piece connecting that to the bogie pivot cross member, which are made up of electrically welded steel plating. At first sight, it would appear that the use of light alloys, of which the specific weight is about three times smaller than that of steel, ought to give a saving of about 65 % in the total weight of the whole framework. In actual practice the position is very different, since it is necessary to take into account the difficulties involved in effecting the connections between the various parts, and the modulus of elasticity of light metals, which is also about three times smaller than the figure for steel. It is essential therefore to use thicker plates and to increase the number of reinforcing members, in order to reduce the lengths exposed to buckling. In this type of design, it has not been possible to apply the principle of the tubular girder to its full extent, but it has been approached as nearly as possible. As was seen in the previous chapter, it was principally the shortage of steel plate prevailing when the order was placed for the first vehicles in 1942 that led the Swiss Federal Railways to decide to have them made in aluminium alloy. As they are intended for a narrow gauge line where the maximum speed is only 75 km. (46 miles) an hour, their framework could be very much lighter than that of standard gauge coaches.

The problem of effecting joints and forming connecting members between components was very specially gone into; after a critical study of the different welding processes, it was decided to use electric spot welding as much as possible. The side walls of the vehicles are united to the underframe and roof by bolts in order to facilitate the disassembling in the event of repairs. Other connections at points inaccessible to the welding machine are secured by

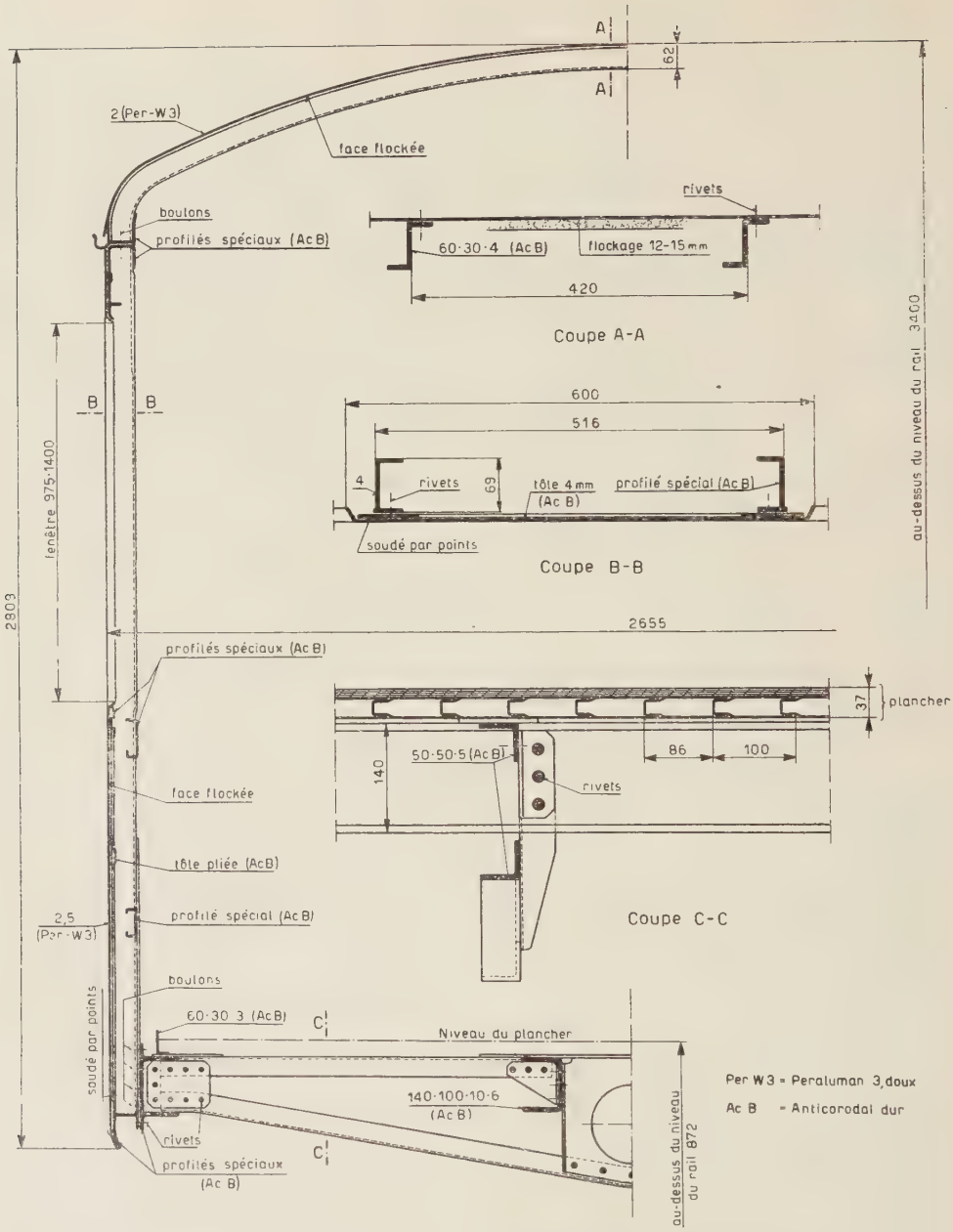


Fig. 26. — Cross section of the framework-body assembly of a light-weight coach for the Brünig line.

Explanation of French terms :

Face flockée = Flock lining. — Boulons = Bolts. — Profilés spéciaux = Special sections. — Rivets = Rivets. — Flockage 12-15 mm. = 12-15 mm. (15/32 to 19/32") of flock. — Coupe... = Section through. — Au-dessus du niveau du rail = Above rail level. — Fenêtre = Window. — Soudé par points = Electric spot welding. — Plancher = Floor. — Tôle pliée = Bent plate. — Niveau du plancher = Floor level. — Per W3 = Soft peraluman 3. — AcB = Hard anticorodal.

rivetting. To reduce the number of these joints, whether welded or rivetted, the aluminium manufacturers produced a considerable number of new sections to meet the coach builder's requirements. The centre portion of the underframe, formed of two U sections, has to take all the stresses and loads arising from the buffing and drawgear. The outside solebars of the underframe as well as the roof supports are formed from special sections assembled by means of spot welding. The floor, the construction of which can be clearly seen in Fig. 26, is made of light metal sections, 27 mm. ($1^1/_{16}$″) high and 100 mm. ($3^{15}/_{16}$″) wide, interlocking with one another and spot welded. This is finally secured to the cross members of the underframe by special studs and in this way strengthens the underframe-body assembly, endowing it with very great rigidity. The weight of the floor is some 400 kgr. (882 lb.) for a surface of 35 m² (377 sq. ft.) or 11.4 kgr./m² (2.334 lb. per sq. ft.) only. The whole framework of the underframe-body assembly weights 3 900 kgr. (3.837 Engl. tons) which represents 30 % of the tare of the vehicle. This is distributed as follows :

Underframe . . . . 1 700 kgr. (3 748 lb.),
Floor . . . . . 400 kgr. (882 lb.),
Side and end walls 1 300 kgr. (2 866 lb.),
Roof . . . . . 500 kgr. (1 102 lb.).

The materials used are hard anticorodal for all sections and soft peraluman 3 for the side and roof sheeting. The former is an alloy which has been subjected to a heat treatment which appreciably improves its mechanical properties, while the latter is a non-heat-treated alloy. Their principal characteristics and composition are given in the table below :

Characteristics.	*Hard Anticorodal.*	*Soft Peraluman 3.*
Tensile strenght kgr./mm²	32- 42	22-26
Elastic limit kgr./mm²	27- 38	10-14
Elongation . . . %	10- 14	18-26
Brinell hardness fig.	90-120	50-65
Specific weight. . .	2.7	2.65
Composition.		
Silicium . . . . %	0.5-1.5	—
Manganese . . . %	0.5-1.0	0-0.4
Magnesium . . . %	0.5-1.0	2-3
Aluminium . . . %	remainder.	remainder.

Figure 28 shows the inside of the framework and Fig. 27 the outside of the completed underframe-body assembly, undergoing static load tests. The objects of these tests was first and foremost to verify experimentally the calculations made to determine the resistance of the structure and to arrive at the stresses met with in its principal parts. In addition, it was also necessary to check the behaviour of the spot welds under load. The body, treated as a girder, was subjected to a vertical load of 13 tonnes (12.794 Engl. tons) distributed over its entire length and a horizontal compression load of 60 tonnes (59.052 Engl. tons) applied at the centre of the headstocks at about the level of the automatic coupling. These loads were applied gradually, at first separately and then together. The deflections of the underframe with the deformations produced in the sheathing and the principal component members of the structure were measured at the most exposed positions. In addition, an oscillatory test was made to determine the natural frequency of oscillation of the whole system. All the tests gave very satisfactory results, proving the excellent behaviour and holding power of all points of connection in the structure. The

Swiss Federal Railways.
Light-weight coach for the Brünig line.

Fig. 27. — Static load test.

Fig. 28. — Interior view of the framework.

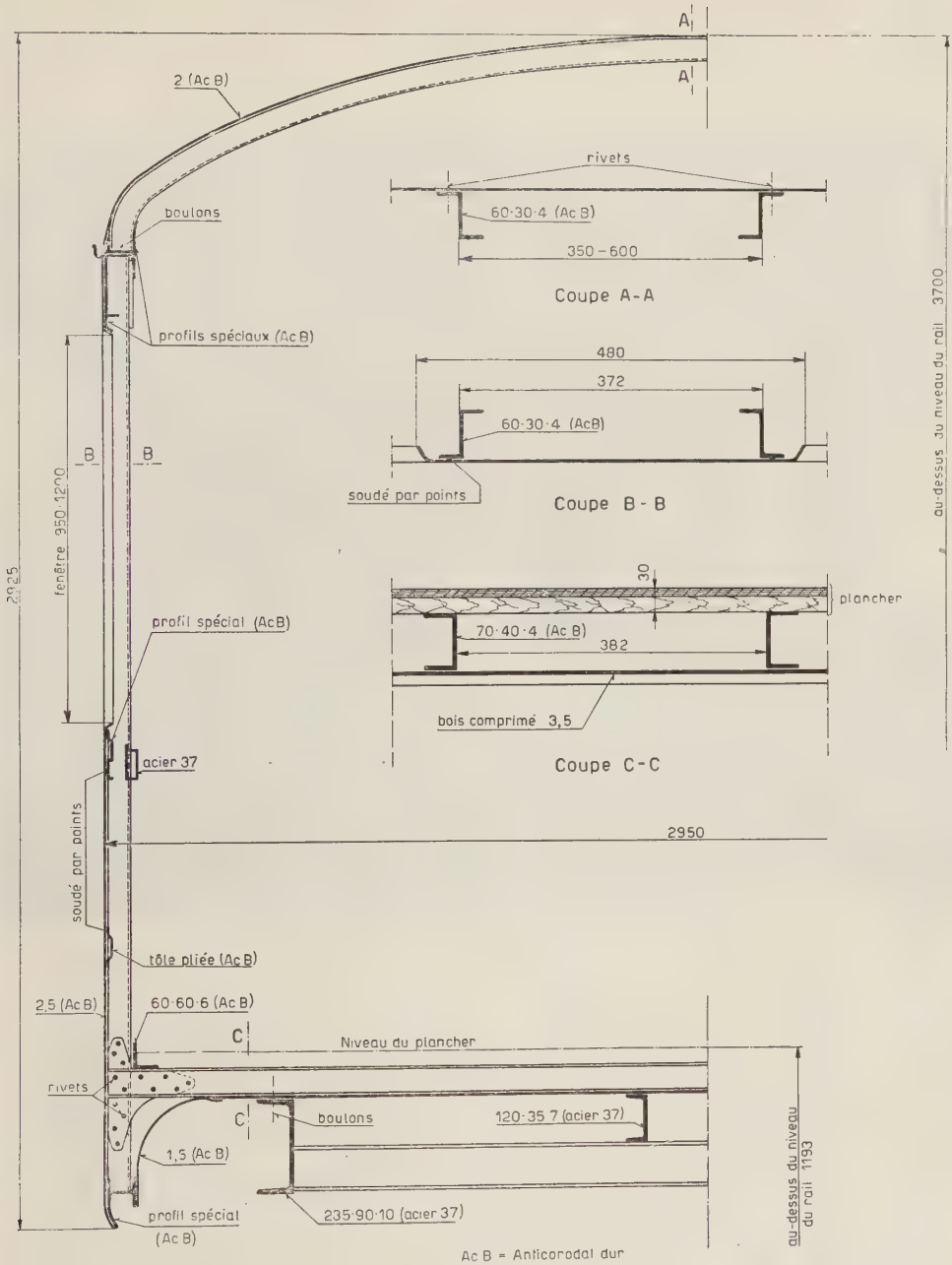


Fig. 29. — Cross section of the framework-body assembly of a light-weight coach for secondary lines.

Explanation of French terms :

Boulons = Bolts. — Rivets = Rivets. — Coupe... = Section through... — Profils spéciaux = Special sections. — Soudé par points = Electric spot welding. — Fenêtre = Window. — Au-dessus du niveau du rail = Above rail level. — Plancher = Floor. — Bois comprimé = Compressed wood. — Niveau du plancher = Floor level. — Tôle pliée = Bent plate. — AcB anticorodal dur = Hard anticorodal.

Swiss Federal Railways.

Fig. 30. — Interior view of the framework of a light-weight coach for secondary lines.

stresses calculated from the actual deformation measurements are well below the elastic limit of the materials.

The framework of the underframe-body assembly of the light weight coaches for secondary lines (Figs. 29 and 30) were constructed on the same principles. It is a mixed design, in which a light alloy body is carried on an ordinary steel underframe, which itself bears all the loads involved, whether vertical or horizontal. The same sections were used as in the Brünig line coach, but the design was simplified. The side walls are rivetted to the light metal U shaped cross members through a gusset plate. The cross members are bolted to the underframe with a sheet of compressed wood between to insulate the steel from the light metal parts. Fig. 31 shows the details of these jointing members. The weight of the framework of the type BCF[4] is about 7 t. (6.889 Engl. tons), 4 t. (3.936 Engl. tons) for the underframe and 3 t. (2.952 Engl. tons) for the body. The saving in weight does not amount to much compared with a steel tubular form of construction of similar dimensions. The object of this new design is

Swiss Federal Railways.

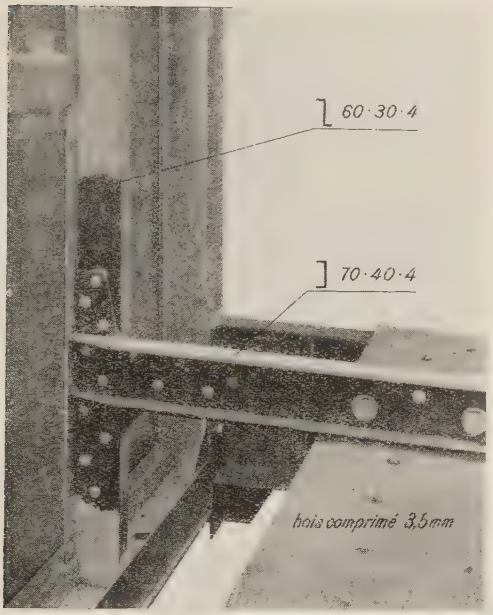


Fig. 31. — Detail of Fig. 30 showing the connection between the upright and the cross members.

to test out in normal service the behaviour of light alloys in general and that of electric spot welding in particular.

As regards the arrangements adopted by the various Administrations for the purpose of obtaining a good level of heat and sound insulation, we find that the process of applying flock to the inside faces of the sheathing is the one most usually adopted. This process consists in applying by means of a spray-gun a paste composed of a mixture of asbestos and a special binding material. This layer, the thickness of which varies in the different countries, is fireproof and has the advantage of preventing the sheeting from vibrating.

The use of plates of a constantly decreasing thickness necessitates special measures being taken to prevent corrosion. Protection against this risk is given as a rule by one or more coats of paint, one with a base of lead minium. In certain cases, the metal surfaces are cleaned by sand blasting before applying the paint. The former French Est Company got over this difficulty by providing at the base of the sheathing special arrangements for draining off any water caused by condensation. The Spanish Railways and Swiss Federal Railways use a steel containing 0.3 to 0.6 % of copper for the side and roof sheets.

With the light alloy and steel designs great precautions have to be taken to eliminate the risk of corrosion and parts in contact are first given a cost of bituminous paint or a zinc base paint.

Certain Administrations report having carried out static load tests on the complete framework of the underframe-body assembly, before the addition of the internal fittings. Most of the tests were carried out with a vertical load uniformly distributed throughout the length, the deflection of the structure being measured. The Swiss Federal Railways submitted the framework of their first light weight vehicle to a complete series of tests under a vertical load of 15 t. (14.763 Engl. tons) and a horizontal one of 100 t. (98.420 Engl. tons) applied at the buffers. The hydraulic presses available did not permit of going to 200 t. (196.840 Engl. tons), the figure provided for in the calculations. Such tests are certainly of value to the builder of a vehicle, as they enable him to verify the accuracy of his calculations relating to the resistance of the structure, but they furnish only a very vague guide to the way a coach is likely to behave in case of collision. Nevertheless the measurements taken in the course of applying the two kinds of load do enable one to discern which parts are liable to be overloaded and therefore to

apply the requisite strengthening. This was the case with the prototype light weight steel coach for the Swiss Federal Railways, described in the preceding chapter.

The Swedish State Railways apply a vertical load of 30 t. (29.526 Engl. tons), and the Italian State Railways one of 44 t. (43.305 Engl. tons) for static tests on their light weight main line vehicles. Other managements content themselves with applying tensile and bending tests to test pieces cut from the materials used. The French National Railways up to the present have only made static load tests — using a press or tensile type testing machine — to the components of the underframe and body. They intend to set up a laboratory where they can be subjected also to dynamic load tests.

* * *

III. Designs of bogies.

Reference to Table I shows that bogies account for a very important part of the deadweight of any vehicle, of the order of 25 and 38 %, according to the extent to which lightening processes have been applied. In the majority of the bogies considered, the weight reduction reported is only some 10 to 15 %. The cause for this low figure is to be found in the fact that the greater part of the components of bogies have been standardised. We are dealing with interchangeable parts which it would be impossible to lighten without making considerable alterations to their form and dimensions, which would of course give rise to an increase in types and parts in stock, and ultimately to higher maintenance charges.

The Swiss Federal Railways, however, are using for their light weight steel coaches an entirely new design of bogie, giving a saving of 40 % in weight, the details of which will be dealt with in this chapter.

It must be stressed that the bogies are in direct permanent contact with the track and are subjected in consequence to all the blows and jerks caused by inequalities therein and by running over the rail joints. They have therefore to be designed to withstand especially considerable stresses and to possess robustness and long life in trying service conditions. In addition, the method of constructing them, especially their suspension gear, exercises a direct influence on the speed at which a vehicle can be permitted to travel. These are no doubt the reasons why we have not come across any parts built of light alloys. These appear to be, for the present at least, ruled out for this class of work.

The chief means resorted to to get a general reduction of weight on bogies may be summarised as follows :

1. Reducing the wheelbase and wheel diameter ;

2. Use of axles with monobloc type wheels, having thin undulating or dished type webs and hollow axles ;

3. Frame and bolster of hollow design with high moment of inertia, made of flat plate bent or stamped to shape, and assembled by electric welding.

Generally speaking, the greatest savings in weight have been effected in the frame and the bolster. The reduction in the axle loading brought about by the general lightening of the vehicle permits also of some cutting down of the dimensions of the axle and wheel assemblies and the axle boxes. Reducing the unsprung weight is of great importance in a light-weight type vehicle as a suitable relative value must be maintained between the weight which is spring-borne and that which is not.

We shall first examine the Pennsylvania type of bogie, much the most widely used in the countries covered by our enquiry.

In France, the former Est Railway effected in 1936 a number of improve-

ments and reductions in weight in a bogie of this type intended to be used with its light weight suburban stock. The principal steps taken were :

1. Axle of standard design retained, but lightened by a bare 70 mm. ($2\frac{3}{4}$") dia. Weight saved 140 kgr. (308 lb.) ;

2. Axle boxes lightened by thinning the walls, saving 50 kgr. (110 lb.) ;

3. Body of wheel with solid cast steel dished web, saving 160 kgr. (352 lb.) ;

4. Equalizer bars of monobloc form in E.S. cast steel of 50 kgr./mm² (31.75 Engl. tons per sq. inch.) tensile, saving 160 kgr. ;

5. Reduction in the frame itself of all thicknesses to a minimum of 10 to 12 mm. $^{25}/_{64}$ to $^{30}/_{64}$"), simplifying the design at the same time, and making use of monobloc construction throughout, all assemblies being electrically welded, bringing the weight down from 1 210 to 935 kgr. (2 667 lb. to 2 060 lb.), a saving of 275 kgr. (607 lb.) ;

6. Use of E.S. cast steel in the bolster and application of the tubular principle in the design of the casting, saving 45 kgr. (99 lb.) ;

7. Other savings of weight were effected in the brake rigging by a judicious use of cast steel, saving a further 100 kgr. (220 lb.).

Altogether the unsprung weight was reduced by 510 kgr. (1 124 lb.) and the springborne by 420 kgr. (926 lb.), a saving of 930 kgr. (2 050 lb.), or 15 %, an appreciable figure at the date in question. On the other hand an improvement in the working of the pivot was obtained through a 30 % diminution of the load on it, evenly distributed over the two flexible shock absorbers. The purpose of this arrangement also was to diminish the hunting movements of the bogies.

In their new main line and branch line coaches, the French National Railways have retained the Pennsylvania bogie to simplify maintenance, whilst effecting further improvements and savings in weight. Fig. 32 shows views of this design which, in the opinion of qualified judges, is so far the most satisfactory for the speeds now obtaining, as much from the point of view of stability and comfort as from that of first cost and upkeep. Its total weight will come to about 4 900 kgr. (10 802 lb.), a reduction of 900 kgr. (1 984 lb.) or 15 %, on that of the 1938 main line stock, in which some reduction had already been effected. The following table shows how the reduction is distributed among the component parts :

Component.	*Weight in kgr.*		*Reduction.*
	1938 type.	*1946 type.*	
Frame	715	610	105
Axles with wheels	2 350	2 010	340
Axle boxes	360	270	90
Equalizer bars	640	470	170
Bolster	250	200	50
Spring suspension items	420	360	60
Springs	560	560	—
Brake rigging	415	360	55
Total	5 710	4 840	870

The wheelbase has been brought down to 2.40 m. (7'10½") the wheel diameter being left at 920 mm. (3'¼"). There is a 60 mm. (2 23/64") bore through the axle which is of semi-hard carbon steel. The wheels have a web at right angles to the axle with 65 mm. (2 9/16") thick tyres added afterwards. The axle boxes may be one of the three types, using oil pad lubrication, mechanical lubrication,

French National Railways.

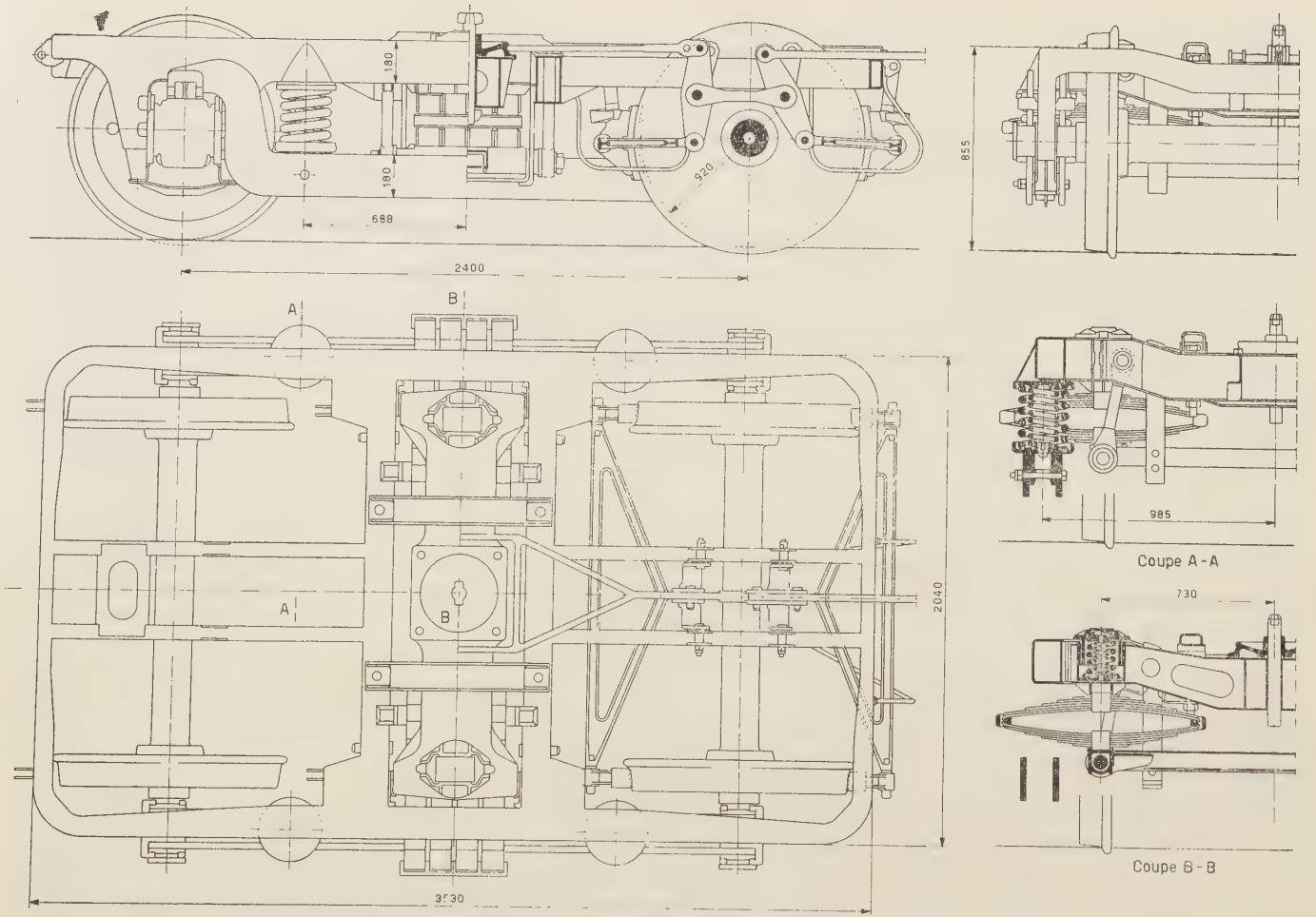


Fig. 32. — Pennsylvania type bogie for the new coaches. Weight : 4 840 kgr. (10 670 lb.).

Explanation of French terms :
Coupe A-A (B-B) = Section through A-A (B-B).

or roller bearings. All three have been lightened. The frame is in mild steel boiler plate, with pressed components electrically welded. The central pivot has been relieved of 60 % of its load, thanks to the permanent action of shock absorbers controlled by spiral springs. This arrangement provides a simple means of eliminating or reducing hunting.

Finally, in order to find out what are the limits to this process of getting rid of weight, the French National Railways have designed a new type of bogie, of which two prototypes are under construction. Its leading feature is the separation effected between the suspension and shock absorbing components. The first comprises a two stage system of very flexible spiral springs, the second hydraulic shock absorbers of a type not as yet described, which retard the expanding action of the springs only in accordance with a law in principle strictly aperiodic. The springs of the primary part of the suspension (axle to frame) are set directly over the axle boxes, enabling equalizers to be dispensed with. The axle boxes further have connecting rods associated with them, designed to stop any longitudinal movement of the axles, so getting rid of an important source of hunting and hence of discomfort and wear of tyres and rails. The wheelbase has also been reduced compared with the Pennsylvania bogie and is to be but 2.25 m. ($7'4^{19}/_{32}''$). The frame in semi-hard steel is formed of stamped and welded parts. The weight is put at 4 350 kgr. (9 500 lb.) which will allow of a saving of one tonne (0.984 Engl. ton) in the dead weight of the vehicle.

The Belgian National Railways are retaining with their light weight vehicles of the first category the Pennsylvania type bogie, whilst lightening it to the extent of some 10 % by the use of light alloys for the brake rigging and some parts of the suspension gear. The total weight of the finished bogie will be some 5 400 kgr. (11 905 lb.). In the case of coaches in which all parts are to be lightened, the selection of the lightest weight bogie is to be made after a comparative investigation bearing on the type and style of construction. It is hoped to obtain one weighing only 4 100 kgr. (9 038 lb.), i.e. lightened by 40 % compared with present types.

The Spanish Railways have equipped all their new coaches with a Pennsylvania bogie (Fig. 33). The axles with their wheels of 1 006 mm. ($3'3^{39}/_{64}''$) diameter are of the normal type. The frame and bolster are of welded press platework. The reduction in weight has been effected principally on these two parts to the extent of 22 %. This bogie weighs 6 400 kgr. (14 109 lb.), a reduction of 1 000 kgr. (2 204 lb.) compared with the same design in cast steel.

The Hungarian State Railways are using a Pennsylvania all-welded type bogie for their light weight stock intended to run in the international trains. The equalizer bars are straight and placed inside the frame. The wheelbase is 2.50 m. ($8'2^{7}/_{16}''$), wheel diameter 1 020 mm. ($3'4^{7}/_{32}''$), and the weight amounts to 6 550 kgr. (14 440 lb.).

The coaches for service inside the country have a bogie in which the bolster has been done away with (Fig. 34). The weight of the body is carried entirely by two lateral supports controlled by two longitudinal leaf springs placed inside the frame. The spring suspension of the axles is effected by means of coil springs located on each side of the roller bearing boxes. The wheelbase has been increased to 2.95 m. ($9'8^{4}/_{32}''$), and the wheel diameter reduced to 920 mm. ($3'\frac{1}{4}''$). A bogie complete weighs 5 100 kgr. (11 243 lb.).

The Italian State Railways are using a type 28 bogie, the framing of which is formed of U section steel of 50 kgr./mm^2 (31.75 Engl. tons per square inch) ten-

Spanish National Railways.

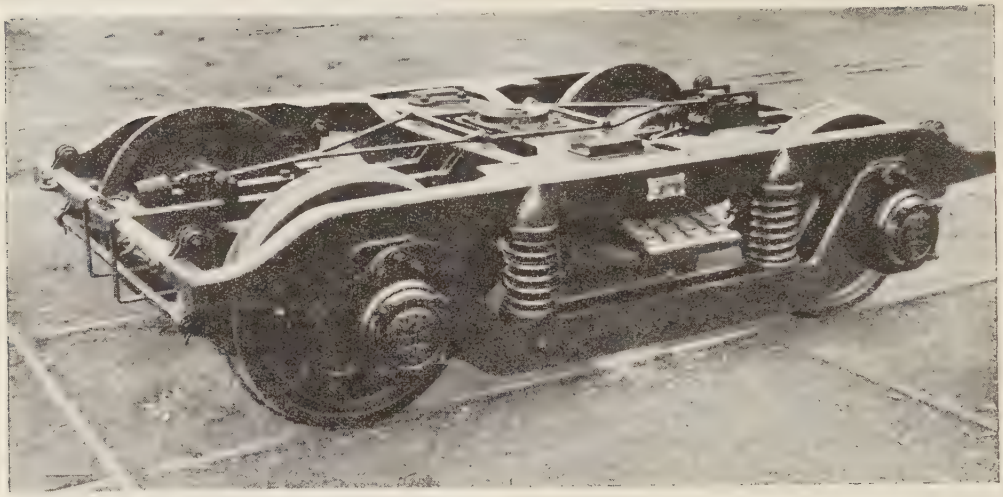


Fig. 33. — Pennsylvania type bogie.
Wheelbase : 2.50 m. ($8'2^{7}/_{16}''$). Weight : 6 400 kgr. (14 109 lb.).

Hungarian State Railways.

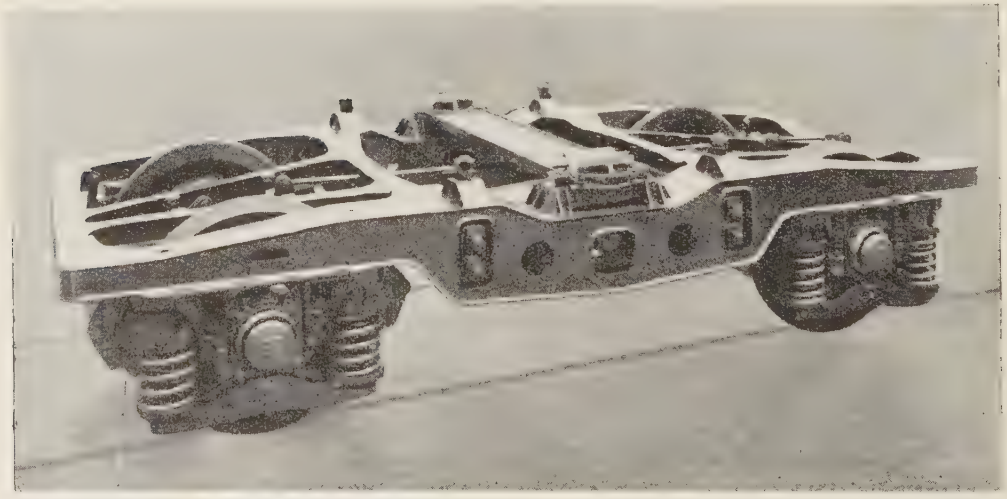


Fig. 34. — Bogie of a class Cak coach.
Wheelbase : 2.95 m. ($9'8^{1}/_{8}''$). Weight : 5 100 kgr. (11 243 lb.).

sile, electrically welded. The centre pivot has to transmit only the horizontal tractive and braking efforts, so allowing the bolster to be lightened. The latter is formed of electrically welded plates and sections of ordinary mild steel. The elastic shock absorbers take the entire weight of the body and are under the control of two sets of springs, both coil and leaf, arranged to function in series. The design provided for using wheel and axle assemblies of the « Bochumerverein » pattern, but the war made it impossible to construct them. The wheelbase is 2.80 m. (9′2¼″) wheel diameter 1 010 mm. (3′3²⁵/₃₂″), the reduction in weight obtained being 650 kgr. (1 433 lb.) or 10 %. The bogie weighs 5 650 kgr. (12 456 lb.).

The Polish State Railways are using a bogie of 2.80 m. wheelbase, with roller bearing axle boxes controlled by connecting rods. The only step taken towards lightening the design has been to apply electric welding to the building of the frame and bolster. The weight is about 7 000 kgr. (15 432 lb.). The centre pivot takes the whole weight of the body. Each stage in the suspension system is effected by using leaf springs in series with helical springs.

The Rumanian State Railways are using the « Wumag » bogies in their lightweight rolling stock. The wheelbase is 3 m. (9′10¹/₈″) and wheel diameter 1 000 mm. (3′3³/₈″). Cast steel axle boxes are fitted of 55 kgr./mm² (34.92 Engl. tons per sq. inch) tensile, with SKF roller bearings. The frame and bolster are in a 52 kgr./mm² (33.01 Engl. tons per sq. inch) tensile steel, electrically welded. The primary and secondary suspension gear have leaf springs and helical springs in series. The total weight reduction is 3 t. (2.952 Engl. tons) compared to the normal bogie and the lightweight design weighs only 4 t. (3.936 Engl. tons).

The Swedish State Railways have no specially light weight bogies. Type 39 is applied to both main-line and suburban vehicles. It has a wheelbase of 3 m. (9′10¹/₈″) and weighs 5 800 kgr. (12 789 lb.). Type 42 has a 2.40 m. (7′10½″) wheelbase and is used for sleeping and restaurant cars. It weighs 6 300 kgr. (13 889 lb.). In both cases the frame is of ordinary mild steel, welded throughout, giving a saving of about 800 kgr. (1 763 lb.).

In the case of the light steel centre corridor coaches of the Swiss Federal Railways, the « Fabrique Suisse de Wagons et d'Ascenseurs » at Schlieren (SWS) undertook to design and make a new type of very light weight bogie (Fig. 35). The wheel and axle assembly is of the « Uerdingen » type with hollow forged axles of 70 to 80 kgr./mm² (44.44 to 50.79 Engl. tons per sq. inch) tensile steel and monobloc or solid one piece wheels, 900 mm. (2′11½″) diameter, with thin web with radial undulating ribs. The solid type of wheel was selected in order to get rid of the risk of tyres slipping, a somewhat frequent occurrence on the Swiss Federal Railways where there are many long heavy gradients. The weight of the wheel and axle assembly is only 658 kgr. (1 450 lb.) against 1 250 kgr. (2 756 lb.). In order to eliminate heating of the bearings and to reduce frictional resistance and cost of upkeep, axle boxes with pivoted roller bearings have been fitted. The keep plates, subjected to rapid wear, have been abolished. The primary suspension gear is formed of two pairs of helical springs placed on each side of the axle box and bearing on it. The blows taken by the axle are in some degree absorbed by rubber pads placed under the springs and further by an oil shock absorber on the patented SWS system (Fig. 37), which itself serves to help keep the axle in line longitudinally. The oscillations are damped out by the oil feeding its way through small openings. This very effective device has, however, the dis-

Swiss Federal Railways.
Bogies for light weight steel coaches.

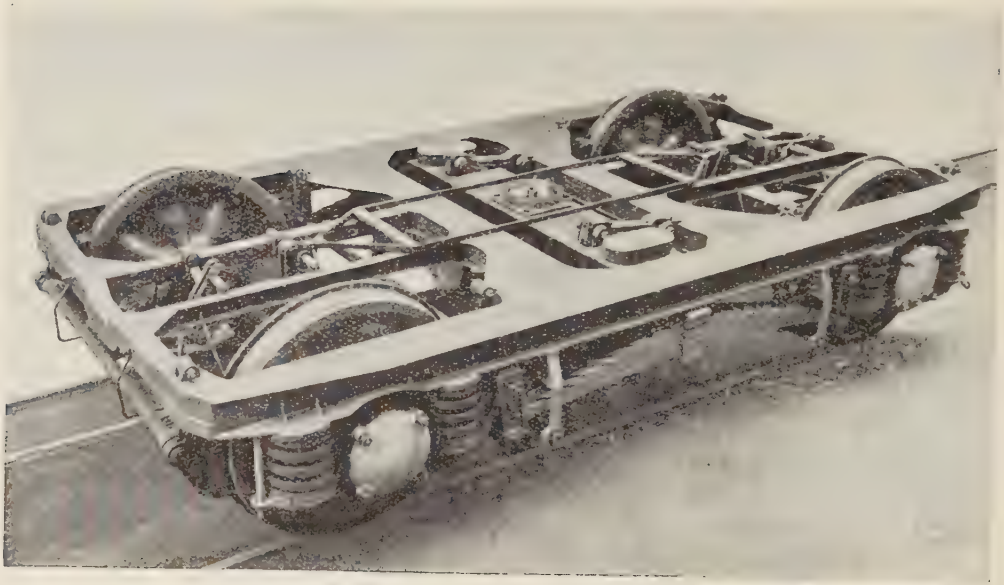


Fig. 35. — Type SWS. Wheelbase : 2.70 m. (8′10¼″). Weight : 3 550 kgr. (7 826 lb.).

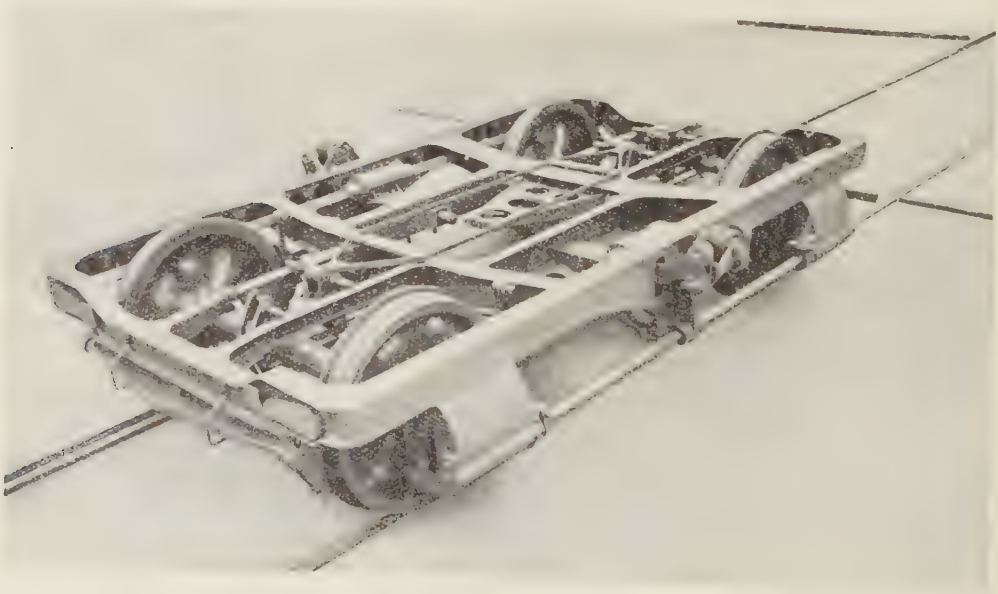


Fig. 36. — Type SIG. Wheelbase : 2.70 m. (8′10¼″). Weight : 3 630 kgr. (8 002 lb.).

Swiss Federal Railways.

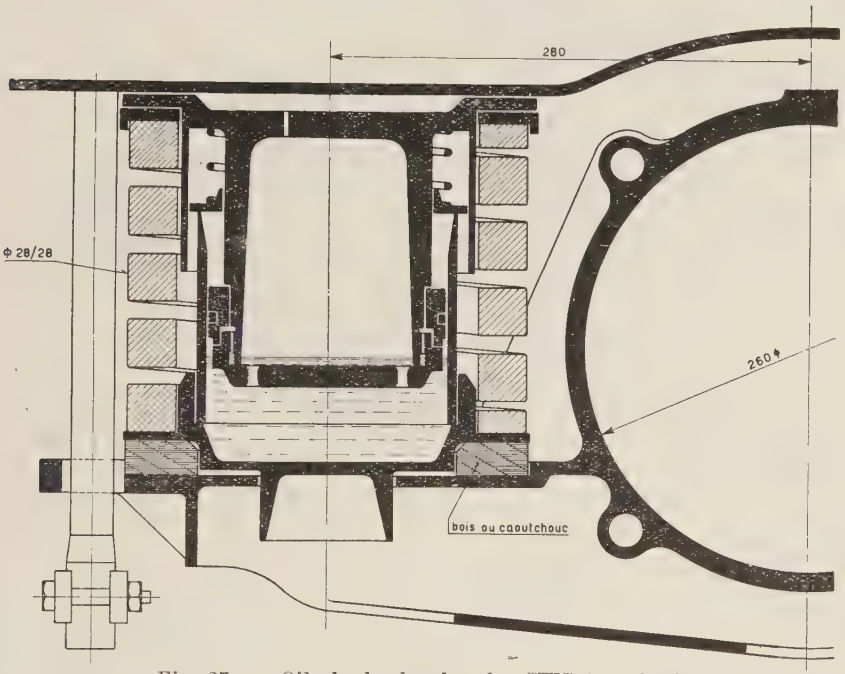


Fig. 37. — Oil shock absorber for SWS type bogie.

Explanation of French terms :
Bois ou caoutchouc = Wood or rubber.

advantage of damping out the oscillations of the spring itself equally in both directions. The frame and bolster are of mild steel plate, electrically welded, their weight being got down as much as possible by selecting sections having the maximum moment of resistance. The total weight of the body is transmitted to the frame through the pivot, the bolster and two stout longitudinal laminated springs carried by inclined connecting bars, providing a centering effect. The great length of the leaf springs and their position between the wheels did not permit of much reduction being made in the wheelbase, which is 2.70 m. (8′10¼″). Longitudinally the bolster is kept in place by two connecting rods. It has a lateral play of 45 mm. (1⁴⁹/₆₄″) on each side. The lateral movements of the bolster and hence the body, which are the ones most felt by passengers are damped by a Broulhiet type oil shock absorber attached on the one side to the frame and on the other to the bolster. As there is an appreciable difference between the dead weight (27.5 t. = 27.065 Engl. tons) and the maximum useful working load of 15 t. (14.763 Engl. tons), or 200 passengers, two additional leaf springs have had to be added to duplicate the principal springs, in order to prevent the latter from being unduly deflected. These additional springs come into play when the useful load reaches 4 500 kgr. (9 920 lb.) or 60 passengers; this results in the springing being very easy and responsive, both

under light and heavy loads. The brake rigging, the brake shoes, and their holders, have also had their weight cut down, thanks to very careful design and construction, and a large use of electric welding. The following table gives the details of the weights for the SWS type bogie.

Component.	*Weight.*
	kgr.
Welded steel frame	500
Bolster	200
Axles with wheels	1 370
Axle boxes	290
Suspension springs	500
Broulhiet shock absorber	50
Guiding components	200
Brake rigging	300
Various accessories, painting, etc.	140
Total weight	3 550

The unsprung weight represented by wheels, axles, axle boxes and coil springs with their supports amounts to 1 880 kgr. (4 162 lb.) per bogie, or 53 % of the total weight, and 13.7 % of the mean dead weight of the vehicle. The biggest reduction is to be found in the frame, where the weight has fallen from 1 200 to 500 kgr. (2 645 to 1 102 lb.), and the total figure, compared with the normal welded type bogie weighing 5 850 kgr. (12 896 lb.) is 2 300 kgr. (5 070 lb.) or a saving of 39.4 %.

The light weight side corridor coaches of the AB^{4ü} series have a special bogie (Fig. 36) designed by the « Société Industrielle Suisse » at Neuhausen (SIG). The leaf and spiral springs have been abolished and replaced by a neat system of suspension by means of torsion bars. The body rests on two lateral supports connected by a system of levers to a first set of torsion bars placed inside the frame and firmly screwed to its front cross members. There is no bolster, properly speaking. It is substantially replaced by the shell of the frame, which is carried on roller bearing axle boxes by rod connections attached to the torsion bars, which take the place of the coil springs in the SWS design. The tension of these bars can be regulated easily, and hence the height of the buffers. The centre pivot connecting the body with the bogie only transmits the guiding and braking forces and has been placed as low as possible in order to improve the running. Import difficulties resulted in the first two bogies only having « Bochum » type axles, similar to those of the SWS bogies. Those of the subsequent coaches have hollow axles and monobloc wheels of cast steel, made in Switzerland, and weighing 750 kgr. (1 653 lb.), the wheelbase, diameter and brake rigging remaining the same. The complete bogie weighs 3 630 kgr. (8 002 lb.), whereas the normal bogie, of 3 m. (9′10$^{1}/_{8}$″) wheelbase with 940 mm. (3′1″) wheels weighs 5 660 kgr. (12 477 lb.), a saving of 2 030 kgr. (4 475 lb.) or 36 %. One of the bogies carried the lighting dynamo with its driving attachment, increasing the weight to 3840 kgr. (8 465 lb.).

This new bogie, patented by the SIG, makes the coach remarkably smooth running. However, as soon as tyre wear reaches a certain amount, it becomes unsteady and the oscillations attain a large amplitude, so that the passengers' comfort becomes seriously affected. This is due to the fact that frictional resistance is not met with in all components of the suspension gear and has been overcome by a Broulhiet oil shock absorber on each of the two torsion bars of the body.

The light weight Brünig line coaches each have an adhesion bogie (Fig. 38) and a rack bogie, both built by SIG, of 1.80 m. (5′10$^{7}/_{8}$″) wheelbase and 700 mm. (2′3½″) wheels. The axles are suspended with respect to the frame by a double set of helical springs placed on each side of the roller bearing axle boxes.

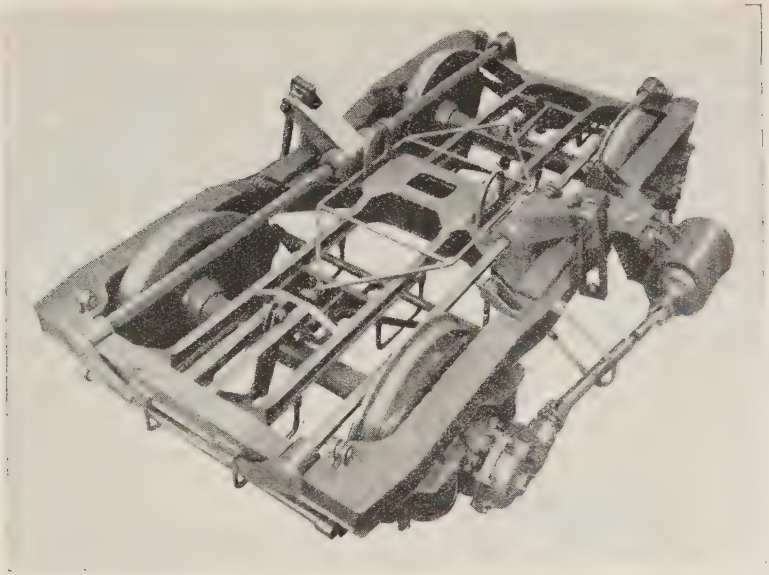


Fig. 38. — SIG type bogie for light weight coaches for the Brünig line.
Wheelbase : 1.80 m. ($5'10^{7}/_{8}''$). Weight : 1 980 kgr. (4 364 lb.).

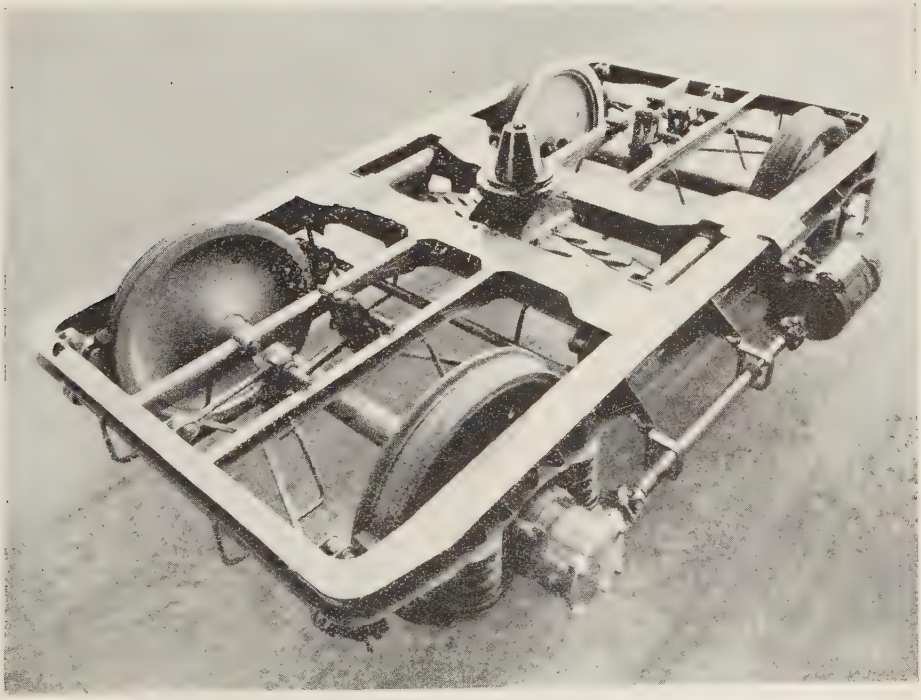


Fig. 39. — SWS type bogie for light weight secondary line coaches.
Wheelbase : 2.30 m. ($7'6^{9}/_{16}''$). Weight : 3 400 kgr. (7 495 lb.).

The secondary suspension is composed of two torsion bars, as on the design just described. The axle assemblies have been lightened by using wheel bodies of hard anticorodal with steel tyres, and by a bore of 50 mm. ($1^{31}/_{32}''$), effecting a reduction of 20 %, and weigh only 400 kgr. (881 lb.). It was decided to use aluminium alloy wheel centres following very satisfactory tests made with sets of such wheels, fitted more than two years ago to some standard gauge stock. The frame, of mild steel plate, is electrically welded throughout. The adhesion bogie carries the lighting dynamo and weighs 1 980 kgr. (4 364 lb.). The rack bogie weighs 2 120 kgr. (4 673 lb.).

The light weight coaches running on secondary lines are to be fitted experimentally with a bogie offering some special features (Fig. 39). The initial suspension is identical with that of the SWS bogie, just described, except that the coil springs have no shock absorbers. The next stage is taken care of by leaf springs, mounted side by side, crossways, taking the place of a bolster. They are suspended from the frame by rods inclined in such a way as to obtain a permanent centering effect. The wheelbase has been brought down to 2.30 m. ($7'6^{9}/_{16}''$). The small dead weight has allowed of the dimensions of the axles and axle boxes being reduced a little; the boxes have somewhat smaller roller bearings than those in the light weight steel coaches. A complete bogie weighs only 3 200 kgr. (7 054 lb.) making it the lightest amongst those brought to our notice.

* * *

IV. Equipment and fittings.

In this chapter we shall deal with the buffing and drawgear, gangways, internal fittings, and heating and lighting equipment. The application of the lightening process to all parts of a coach results in a series of partial savings of weight, which taken individually appear of little consequence, but their sum is generally quite appreciable. Thus, for example, it will be noted from the table on page 176/40 that the total weight of the equipment and fittings on the Swiss Federal Railways light weight steel coach comes to 10 560 kgr. (23 280 lb.), whereas in the case of the heavy type steel coach it amounts to 14 180 kgr. (31 260 lb.), which gives a saving of 3 620 kgr. (7 980 lb.) or 25.5 %. It would take too long to consider the matter in detail, and only the most interesting items will be indicated.

Buffing and draw gear.

The majority of modern coaches are fitted with non-continuous drawgear in which the abolition of the long drawbar rod leads to a saving in weight. The Belgian coaches retain the continuous system, but the two drawgears of usual design are replaced by a single piece of mechanism. In many cases we find faced indiarubber springs used to eliminate weight. The couplings are as a rule made to stand loads up to 65 t. (63.973 Engl. tons) breaking strain, as laid down in UIC regulations. On the other hand the Swiss Federal Railways have reduced this limit figure to 50 t. (49.210 Engl. tons) for all light weight steel coaches, considering it sufficient for trains made up of light weight stock. This, coupled with the use of chrome-nickel steel for coach couplings and the abolition of safety couplings, has enabled a saving of approximately 50 % to be made. In all main line vehicles, the buffers are of the compensated type. The connection is effected by a light design of lever which takes the place of the heavy buffing leaf spring used in previous designs. Fig. 40 shows, by way of example, the construction of the buffing and drawgear on the Swiss Federal Railways light weight steel coaches. The buffer

Swiss Federal Railways.

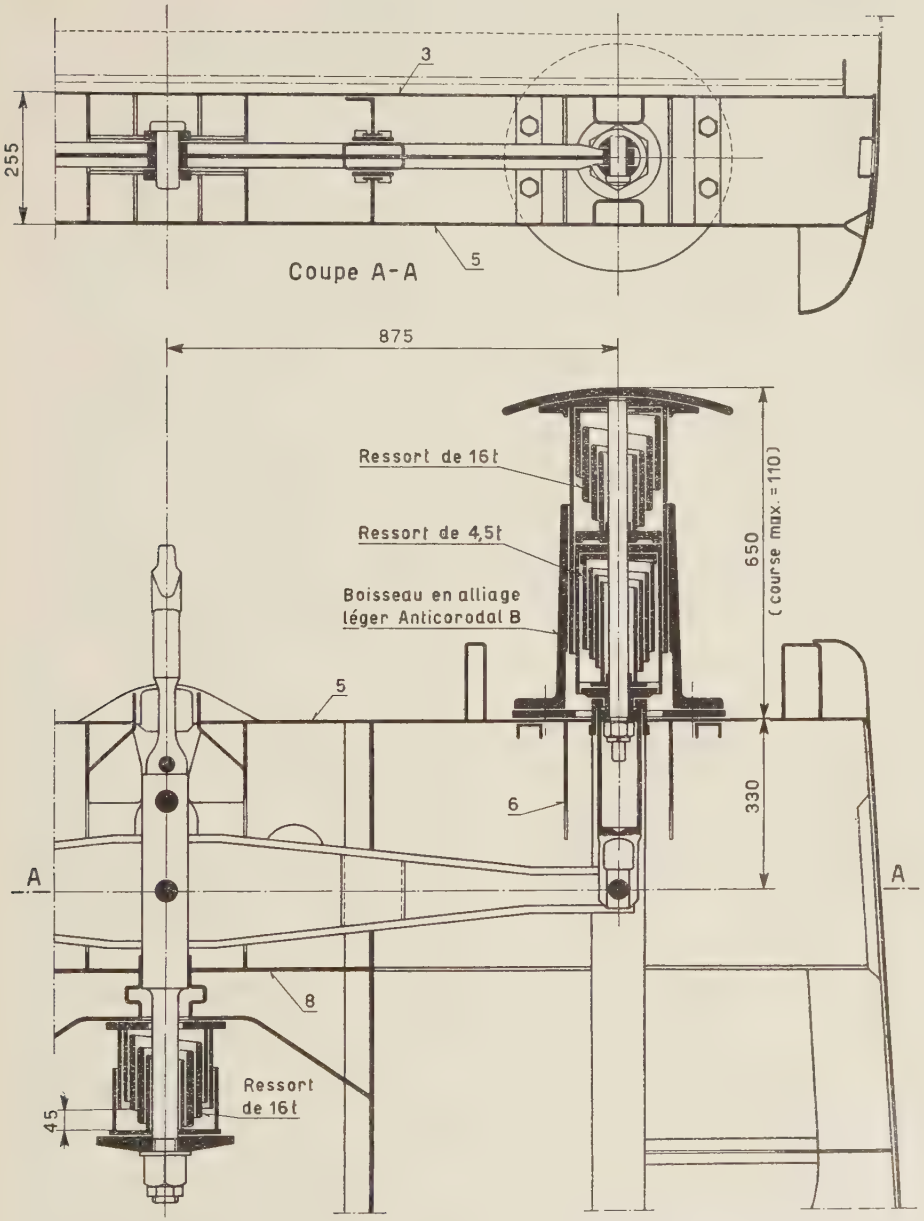


Fig. 40. — Buffing and drawgear for light-weight steel coaches.

Explanation of French terms :

Coupe A-A = Section through A-A. — Ressort de 16 t. = 16 t. spring. — Course max. = Maximum stroke. — Boisseau en alliage léger anticorodal B = Casing of light alloy anticorodal B.

casing in light alloy will be noticed and the light weight compensating lever, as well as the reinforcements applied to the frame. The buffer casing base plate of light alloy in the first coaches, had to be replaced by a steel one, as its centre portion was crushed in by the tube itself striking against it when driven right home. The Pirelli type of rubber springs were replaced during the war by steel volute springs, somewhat adding to the weight. The complete buffing and drawgear of a coach weighs only 650 kgr. (1 433 lb.), a saving in weight of about 50 % compared with previous designs of normal type.

Many managements have, however, adhered to the latter for the sake of simplification and economy in maintenance. Some small reductions in weight have, however, been effected by using electric welding, reducing the thickness of certain components, and by using cast steel tubes for the plunger types of buffer.

Gangway equipment.

The design of this subject to certain international regulations, and the steps taken in a few countries only to cut down the weight comprise the use of light alloys for the framework of the collapsible bellows and the gangway foottreads. About 50 % of the weight is saved in this way.

Brake equipment.

The brake equipment also comprises standardised interchangeable parts, which are used without alteration for certain light weight coaches, where weight reduction has not been systematically studied with respect to every part. However, some very interesting examples of weight reduction have been brought to our notice in connection with the brake cylinders, air reservoirs, brake rigging and piping. The French National Railways have brought out in connection with their new coaches a new one piece brake mechanism of welded pressed plate, bringing together in one light, simple form the cylinder, the reservoir and the fixed point, or main support, for the brake rigging. The saving in weight amounts to 90 kgr. (198 lb.). The streamlined coaches of the former French State lines have a brake the power of which is variable in accordance with the speed, giving a brake shoe pressure of 180 % of the tare weight at 120 km. (74 miles)/h. This is brought back to the normal figure of 80 % when the speed falls below 80 km. (50 miles)/h. This arrangement permits of stopping a train running at 100 km./h. in 600 m. (656 yards). The brake gear is installed complete on each bogie separately, in order to get rid of long and noisy rigging. The reductions in weight effected both on the bogie itself and in the brake gear have the result of leaving the total bogie weight the same as before. This arrangement has, however, been given up for new stock as it entails considerable complications which were felt to be undesirable, such as the duplication of components and the necessity for using flexible connections, with their disadvantages. In the end, the saving in weight obtained is of little consequence. This is the reason why on all the modern light weight vehicles the brake equipment is mounted directly on the underframe. Cylinders and reservoirs are of welded plate, greatly reducing the weight. The rigging and truss rods are lightened by using tubes or plates cut to shape and assembled by electric welding. The weights of the air piping have been likewise cut down by using thin walled steel tubing in place of gas piping.

The Swiss Federal Railways light steel vehicles, used chiefly in fast trains running at higher speeds than the ordinary expresses, have a brake of extra effectiveness, in order to maintain the usual

braking distances. This is called the high speed brake. It consists of an ordinary Westinghouse type brake and an additional one, identical therewith, the dependance of which on the speed is effected by an electro-pneumatic valve controlling a centrifugal cut-out switch mounted on the end of the shaft of the lighting dynamo. This supplementary brake comes in to action at speeds over 80 km./h., providing in combination with the ordinary one, a brake power of 140 %. It is cut out of action when the speed drops below 40 km. (25 miles)/h.; the pressure on the brake shoes is then brought back to the normal figure, 70 % of the dead weight. As the maximum speed of the light-weight trains has recently been raised from 110 to 125 km. (68 to 75 miles)/h., it has been found necessary to strengthen the brake power up to 160 % by modifying the rigging. The two 10 inch cylinders, of light cast steel design, weigh together 76 kgr. (168 lb) only against 175 kgr. (385 lb.) for a cast iron 14 inch cylinder. The reservoirs are of electrically welded plate; the air piping is of drawn steel with thin walls of 2 mm. ($^5/_{64}$″). The entire rigging has been the object of detailed investigations to cut down the weight. The total figure for the brake gear on a light weight coach is 1 330 kgr. (2 932 lb.), of which 600 kgr. (1 322 lb.) represents the rigging on the bogies. whilst for a heavy type coach it is 2 340 kgr. (5 158 lb.), giving 43 % saving in spite of the additional equipment.

The light-weight coaches which the Belgian National Railways are proposing to construct will have a light weight brake equipment comprising welded steel plate cylinders, reservoirs in a weldable light alloy, duralumin rigging and piping and truss rods in cast light alloy. The total saving in weight is about 40 %.

The light weight Brünig line coaches have an automatic adhesion brake and a different rack brake, acting on the drum of the rack pinion. The two systems have each their own cylinder, reservoir and controlling triple valve, the parts of which have had their weight cut down to a particularly fine figure. The reservoirs and the air pipe connections are in hard anticorodal. A 40 litre (8.799 gallons) reservoir weighs 7.5 kgr. (16.5 lb.) against 21 kgr. (46 lb.) for one in welded steel, but it costs four times as much. This simple example is enough to show the obstacles at present met with in applying light alloys generally to the construction of components where the cost of material is a principal factor.

The main train pipe is 22 mm. ($^7/_8$″) external diameter and has very thin walls, 1.5 mm. (0.059 inch.). The entire brake gear for a coach only weighs 280 kgr. (617 lb.), 35 kgr. (77 lb.) being attributable to the hand brake. This figure cannot be compared with those of the vehicles previously referred to as their equipment is different.

Internal fittings.

In the matter of internal fittings we find light weight metals and alloys applied in very varying degrees and effecting noteworthy savings in weight. The covering of the inside faces of the walls, roof and partitions is preferably effected by using compressed wood or plywood, faced or non-faced, in thin sheets, varying from 3 to 6 mm. ($^1/_8$ to $^{15}/_{64}$″) thick, mounted on wooden brackets which are secured to the body framing. In the case of the « Est » light weight suburban coaches and the future French National Railways branch line design, all internal panelling is in aluminium sheet, 1.2 mm. ($^7/_{128}$″) below the cornices and 1 mm. ($^3/_{64}$″) on the roof. The Italian State Railways use pure aluminium for the ceilings of the compartments and the side corridor. The walls are covered with bakelised plywood. The Spanish 3rd. class coaches have 1 mm. steel pla-

tes on the side walls. In the Swiss Federal Railways' light steel coaches we find a special form of compressed wood known as « Pavatex », 3 mm. ($^1/_8$″) thick for the roof and 6 mm. ($^{15}/_{64}$″) for the sides. The AB^{4ü} side corridor Brünig coaches have plywood faced on one or both sides with aluminium sheet. This is lighter than « Pavatex » board — 500 gr. less per square metre (0.1024 lb. per sq. ft.) — but dearer.

The design of the floor is very important from the point of view of protecting the coach from the effects of heat, cold and noise. In the cross-sections of the framework of the underframe-body assemblies we show how the floor is built and need not refer to the details here. In the French National Railways' new coaches the floor, properly so called, in poplar planking, separated from the steel flooring which has its inner face treated with flock by an air space, is carried on wooden brackets with asphalt treated felt placed between. In other designs the space

French National Railways.

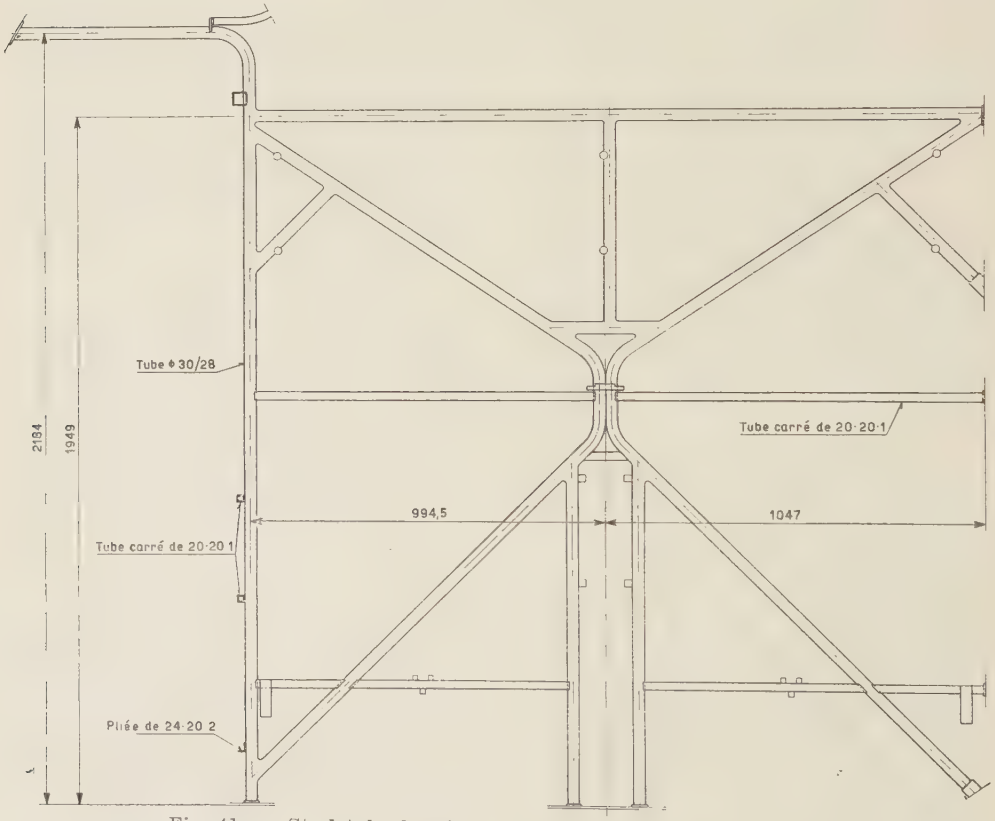


Fig. 41. — Steel tube framing of the compartment partitions.

Explanation of French terms :
Tube carré de = Square tube of 20-20-1. — Pliée de = Bent of 24-20-2.

between the floor plating and the wooden floor is filled with glass wool (Italian coaches) or an insulating material known as « Isoflex » made up of thin leaves of cellulose acetate, creased and applied in several layers (Swedish coaches). Some countries use a very thin crinkled or corrugated plate, which

French National Railways.

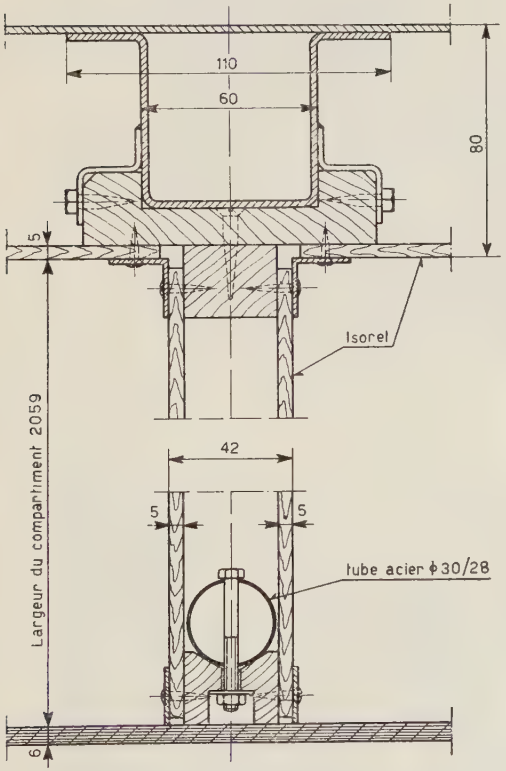


Fig. 42. — Details of the lining of the wall.

Explanation of French terms :

Largeur du compartiment = Width of compartment.
Isorel = « Isorel » insulating material.
Tube acier = Steel tube.

forms at the same time a reinforcement for the framework of the underframe-body assembly. The light weight AB^{4ü} coaches of the Swiss Federal Railways have a special design of floor affording good insulation against noise. It is made of 1.5 mm. (0.059 inch) aluminium plate, rivetted directly to the crossmembers of the underframing and has diamond shaped ribbing, with the spaces filled with grains of cork. Compressed 10 mm. (0.393 inch) cork sheets are secured to this plating by means of a special adhesive. The total thickness of the floor so obtained is only 30 mm. ($1^3/_{16}''$). Above the bogies the cork covering is strengthened by a second layer of the same thickness. We have already in Chapter II referred to the special design of floor used in the Brünig vehicles. The components, in light alloy section, are also covered with compressed cork sheeting.

When speaking in that chapter of the measures taken to counteract corrosion, we remarked that the roof sheets were protected by an insulating layer which also aided in keeping noise away from the compartments. In the French coaches the « Isorel » panels are also faced with flock. The Polish lines apply a 15 mm. ($^{19}/_{32}''$) cork layer. As a rule a wide air space plays the chief part in the roof covering in providing protection against the effects of heat and cold.

The compartment partitions are frequently required to provide transverse reinforcement for the underframe-body assembly and for this purpose are given a steel framing, an example of lightened construction worth noting being provided by the French main line coaches (Fig. 41). This partition made up of very thin steel tube assembled by autogenous welding uses only 14 kgr. (30 lb.) of metal and is very rigid indeed. Fig. 42 shows the details of the way the walls of these new coaches are made up.

Water reservoirs are usually of tinned copper or zinc sheet. The light steel vehicles, as those for the Brünig line, have aluminium reservoirs, the only ones of this type notified to us.

Important savings of weight have been obtained in the construction of doors by

suitable selection of materials and design. In the French main line coaches, the entrance doors are of pressed steel plate with light alloy sheet facing on the inside. The communicating doors at

Swiss Federal Railways.

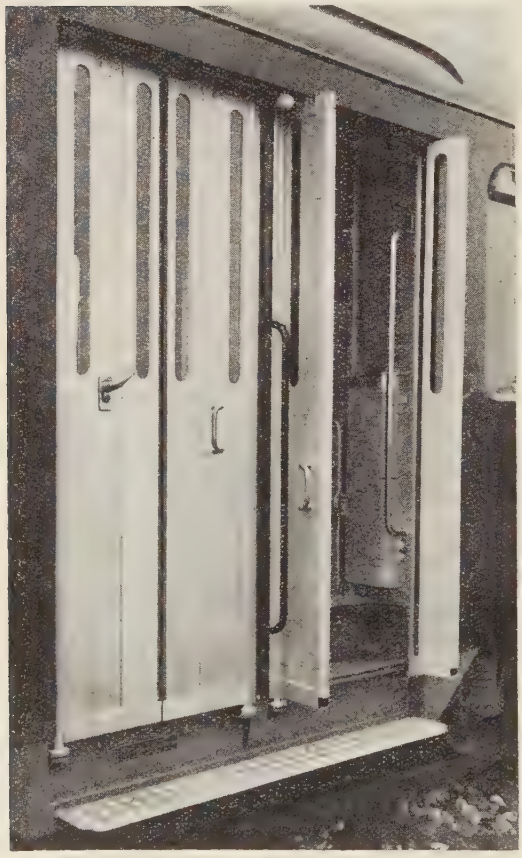


Fig. 43. — Entrance doors made of aluminium alloy for Class C⁴ü light weight steel coaches with central corridor.

the ends and the compartment doors in the 3rd. class carriages only are in rolled light alloy sheet, treated by a patented process giving the outer faces a perfectly smooth finish. The 1st. and 2nd. class carriages have varnished wooden doors. All the doors in the « Est » suburban and branch line coaches are of the sliding type, in light alloy, made in the way just referred to. In the Swiss coaches, the entrance doors are double leaved and hinged to fold back on one another (Fig. 43). Each panel is formed from a special section, cut away on the inside, in anticorodal, the light alloy best known in Switzerland. The use of these special sections, in addition to cutting down the weight, has the advantage of reducing the amount of machining work required. The leaves of the doors are left unpainted, to make them very conspicuous. The compartment doors are of sliding type, in wood covered with aluminium sheet. In the AB⁴ü coaches the entrance doors have two leaves in light alloy, each turning partly outwards, partly inwards, so as not to encroach on the construction gauge when open.

The use of aluminium alloy has likewise been extended to all the subsidiary fittings, such as luggage racks, steps, handles, general metal accessories, window frames, etc. In the Swiss 3rd. class carriages, the framing of the seats and luggage racks is in electrically welded square steel tubing (Fig. 50). This gives an important saving in weight and retains stoutness of construction essential with such items. In the 2nd class carriages (Fig. 49), the luggage racks are in light-alloy tubing.

In many cases the window are in « securit » glass, enabling the thickness to be cut down, with appreciable saving in weight. Unframed glass is now preferred, moved by two knobs or a handle.

Figs. 44 to 53 show the fittings of compartments in some of the vehicles under consideration. They give an idea of the care and taste exercised in their arrangement, with the object of giving the passenger an ever higher standard of comfort and convenience. These

Spanish National Railways.

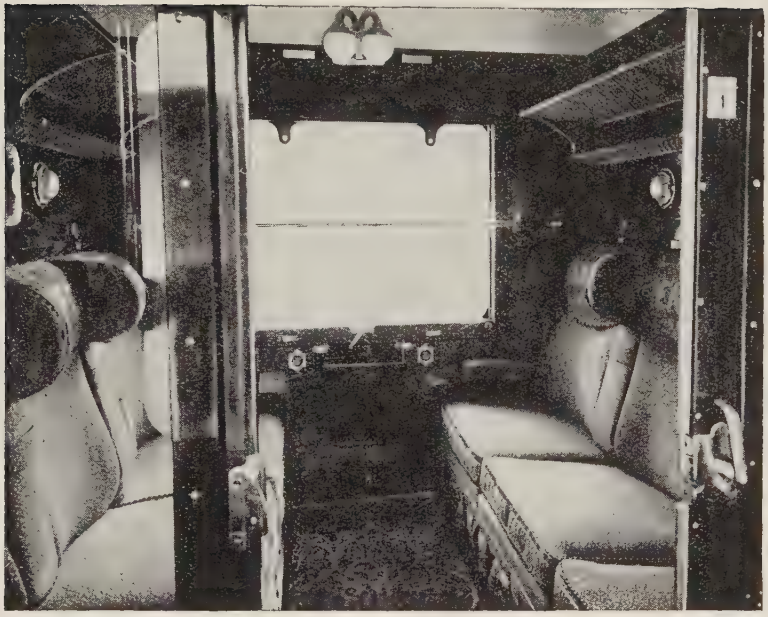


Fig. 44. — 1st class compartment.

French National Railways.

Fig. 45. — 3rd class compartment of a Class C^{10} streamlined main line coach.

French National Railways.

Fig. 46. — 2nd class compartment of a light-weight suburban coach (Est).

Italian State Railways.
Class Cz light weight coach.

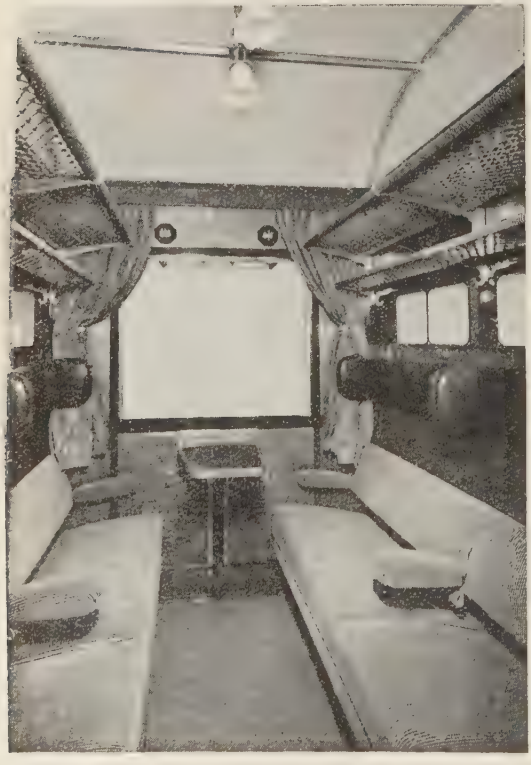


Fig. 47. — 3rd class compartment.

Fig. 48. — Toilet and corridor.

Swiss Federal Railways.
Light weight steel coaches.

Fig. 49. — 2nd class carriage with central corridor.

Fig. 50. — 3rd. class compartment.

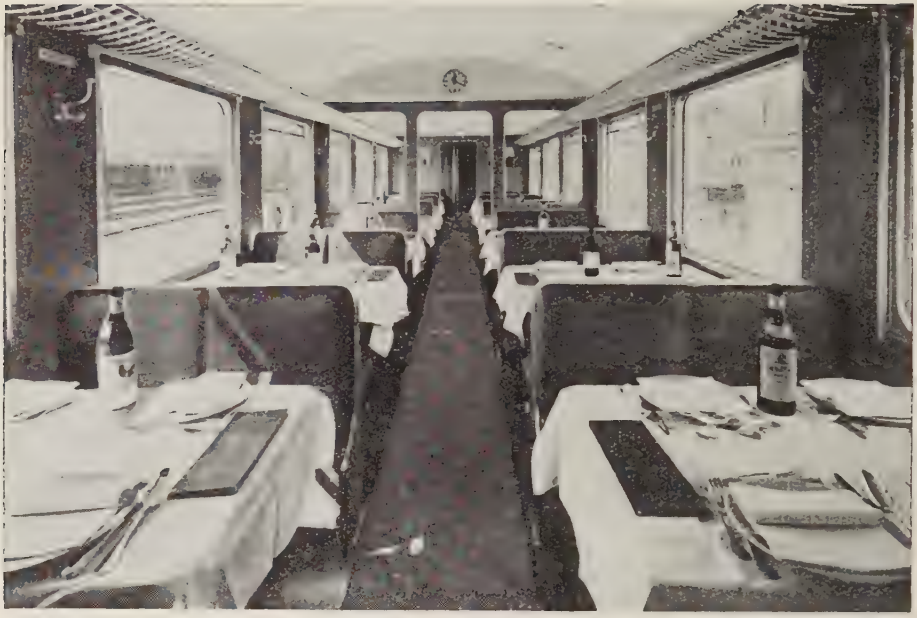


Fig. 51. — Dining room of restaurant-car.

Fig. 52. — 2nd class compartment on Class AB⁴ü coach.

Swiss Federal Railways.

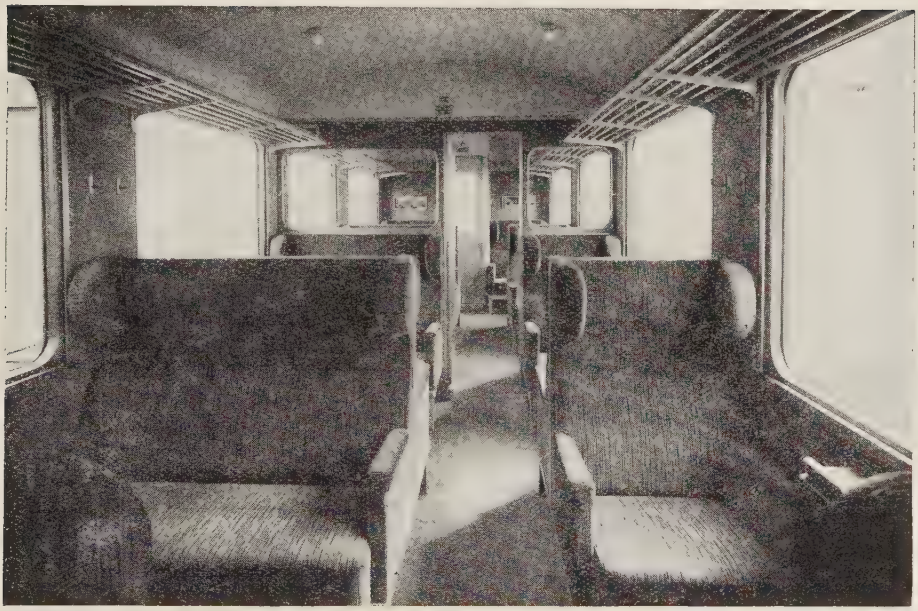


Fig. 53. — 2nd class compartment on a light weight coach for the Brünig line.

compartments are to be noted as having larger internal dimensions than those of earlier designs. The length of the 1st. class carriages varies between 2 100 and 2 300 mm. (6′10$^{11}/_{16}$″ to 7′6$^{9}/_{16}$″), their width between 1 915 and 2 073 mm. (6′3$^{3}/_{8}$″ and 6′9$^{5}/_{8}$″). In the case of 3rd. class carriages, the figures are respectively 1 620 to 1 750 mm. (5′3$\frac{3}{4}$″ to 5′5$^{7}/_{8}$″) and 1 966 to 2 090 mm. (6′5$^{3}/_{8}$″ to 6′10$^{19}/_{64}$″). These relate to side corridor standard gauge stock. The Spanish coaches are of course wider, and afford for example 10 seats in a 3rd. class carriage.

The ventilating attachments of the compartments have not been the subject of any special endeavour to reduce the weight, or improvements. They are still of the static type mounted on the roof which meet with the approval of the Administrations.

As regards the heating and lighting equipment, some interesting savings in weight have been obtained. The steam radiators are now of the Westinghouse pattern, in copper or aluminium. The new French main line coaches will have an electric and steam heating system, working by means of circulated air functioning electrically under the 4 voltages allowed by the UIC, the heated air being distributed under the seats with automatic temperature regulation. This system permits of a small saving in weight, 10 %, over a mixed installation (steam and electric) using radiators.

The heating and lighting equipment used by the Swiss Federal Railways has had its weight considerably reduced. The coupling fittings, such as junction boxes and cable carriers are in silumin light alloy. The weight of a 700 watt radiator has in this way fallen from 6.6

to 3.6 kgr. (14.52 lb. to 7.2 lb.). The lighting dynamo, 2.3 kW. is of modern design and very light, weighing only 90 kgr. (198 lb.), which is only about half the weight of the normal pattern. In addition, the two lighting battery containers have been got rid of, saving 310 kgr. (683 lb.) per coach. The capacity has been reduced from 200 to 100 ampere hours, giving a 5 hours reserve. This has been made possible by replacing the belt by a driving mechanism (bevel gear and cardan shaft) which ensures that the battery shall receive more certain and regular charging. This design, now fixed to more than 400 bogie vehicles — among them all the light weight steel coaches built these last 10 years — is also cheaper to maintain.

In none of the stock considered have we found any air conditioning plant. This would in any case have the opposite effect, as far as reducing weight is concerned. All the Administrations state that no need has been felt for such equipment in the relatively temperate climates of the countries concerned.

V. Results in service.

Those Administrations, which have had light weight metal vehicles in use in sufficient number for several years, report that the results have been very satisfactory. This is notably the case on the French National Railways, the Swedish State lines and the Swiss Federal Railways, which respectively have already put 242, 284 and 179 various types of light weight coaches into service.

French National Railways.

Fig. 54. — Effects of a collision on a metal rivetted coach.

The experience of these three Administrations is very favourable, from both the point of view of comfort and power to withstand accidental shock. All the managements are unanimous in recognising the undeniable advantages which light weight stock offers in service and intend in future to build such stock only.

The numerous accidents that have happened in France with rivetted type metal stock, of which Fig. 54 is a striking reminder, had directed the attention of the designers to the weak point in this form of construction. It is the rivetted assemblies, or those built up by simple spot welds in line that fail first under dynamic stresses. After this the end walls collapse backwards on to the body like a drawbridge, in consequence of their insufficient powers of resistance at roof level. The application, however, of the principle of the tubular girder, arc welded throughout, as described in this report, has eliminated these defects completely.

The Swiss Federal Railways have had so far only one serious accident involving their light weight steel stock. They thus have had experimental proof that it possesses high dynamic resistance in case of collision and consequently a high degree of safety for passengers. This accident happened in the autumn of 1943 as follows : The through Lucerne-Berne train, composed of 11 such coaches, was due to meet a slow passenger train at the Schüpfheim crossing station. At the instant when its last coach but one was clearing the entering facing points, these were irregularly reversed, the leading bogie continuing on the straight track while the rear one took the diverging route and left the rails. This caused coupling to fail between the two rear vehicles, the first being thrown sideways against the locomotive of the waiting train at a speed of 60 km. (37 miles)/h. and heeling over at 30° to the centre line of the track. It rebounded and was thrown to the side of the line but did not overturn, probably because it had a very low centre of gravity. The last coach also struck the front of the waiting locomotive head on at almost the same speed.

As can be seen clearly in Fig. 55 the extent of the damage to the last coach but one is plainly limited to the portion which took the blow. The side wall was driven in by the frame of the locomotive, situated much higher than that of the coach. This caused it to be struck in its weakest part. However, the strengthening pieces round the entrance door assisted in restricting the extent of the damage, resulting in the end compartment being spared. This was also the reason why the coach was thrown to the side by the shock. The other three entrance doors remained in working order, so that passengers were able to alight in the normal manner. Only the seats directly struck were displaced. These details go to prove the great rigidity of the whole assembly, which, outside the area where the blow fell, suffered no appreciable deformation.

The last coach, which had been in service for three years and a half, received a totally different kind of shock, as it practically struck the locomotive head on at 60 km./h. As Fig. 56 plainly shows, only that part of the underframe-body assembly situated between the headstock and the bogie pivot was driven in. At the moment of the blow the locomotive probably only had one buffer left, so that the shock was a very harmful one. The front wall of the coach was struck partly by the locomotive frame and hence above buffer level. It is interesting to note that it remained almost upright, the blow having been distributed equally over all components of the framing which in this way absorbed the enormous kinematic energy of the coach, which was full. The covering sheeting was bent and twisted but not torn in any place, while

Swiss Federal Railways.
Light weight steel coaches seriously damaged in a collision.

Fig. 55. — Lateral shock at a speed of 60 km. (37 miles)/h.

Fig. 56. — Frontal shock at a speed of 60 km./h.

the welds showed themselves to be extremely solid and did not fail. No part of the body beyond the second window of the end compartment suffered the least deformation. All the entrance doors could be opened without difficulty. Only the double seat in the first compartment was displaced.

It should also be pointed out that the damage suffered by the bogies was very slight, since the two coaches were able to travel on their own wheels to the repair shops.

A comparison of Figs. 54 and 56 brings out quite plainly the indisputable advantages of the all-welded tubular type of construction over the old rivetted form, as regards the safety of passengers.

SUMMARY.

As regards the matters forming the subject of the first part of our report, we can say that all the managements we approached acknowledge both the necessity and possibility of reducing the weight of passenger rolling stock.

About the 1930-1935 period, the dead weight of metal type coaches on the main lines varied between 45 and 50 t. (44.289 and 49.210 Engl. tons). The first attempts at reducing it, chiefly by replacing rivetting more or less completely by electric welding, brought it down to 40 t. (39.368 Engl. tons). Finally the adoption of the tubular girder design, the construction of which has been improved following advances made in welding processes and the more extensive use of light alloys, has enabled an average figure of 30 t. (29.526 Engl. tons) to be attained, 32 t. (31.494 Engl. tons) in France and Italy, 28 t. (27.557 Engl. tons) in Switzerland.

The chief reduction has been effected in the metal framing of the vehicles, now forming a homogeneous unit, the underframe, side walls and roof being solidly and closely united together to form a tubular girder. This arrangement results in all component elements sharing in the power of the assembly to withstand shock and enables the thickness of the sheet covering to be reduced. In addition, an ever increasing use is being made of pressed or bent plate, in place of heavy laminated sections for the hooping rings, the sole bars, the various strengthening pieces, etc. As to the metals used, they are, in preference to all others, steels ranging from the ordinary 37 kgr./mm^2 (23.49 Engl. tons per sq. inch) tensile to the semi-hard quality 65 kgr./mm^2 (41.27 Engl. tons per sq. inch) tensile, which are easily welded. Light alloys have as yet only been used for prototype vehicles, and also for mixed designs in which the underframe is in steel and the body in light metal.

Only the 27 Brünig line coaches have the framework of the underframe-body assembly made entirely in light alloy. It must be emphasised, however, that the saving in weight thereby realised is not proportional to the ratio between the specific weights of steel and the alloy concerned on account of the difference between the modulus of elasticity and the difficulties experienced in effecting the welds between components.

The cutting down of the thickness of the plates used as sheathing gives the problem of corrosion a special importance. To check this destructive action, some Administrations make use of copper-steel plate, but generally speaking, the practice is to resort to applying a coat of minium lead paint with flock on the inside surfaces. This last process has the advantage of ensuring a good degree of insulation against the effects of heat, cold and noise, and diminishing any tendency to vibration.

It has been found possible as a rule to reduce the weight of the bogies by shortening the wheelbase, boring the axles, and by using pressed or bent platework assembled by electric weld-

ing for the frame and bolster. The use of standard designs of components, however, makes it difficult to effect any substantial saving. The French National Railways which are using to all intents and purposes none but the Pennsylvania type of bogie, have succeeded in cutting the weight down to 4 900 kgr. (10 802 lb.), while the Swiss Federal Railways have obtained savings to the extent of 40 %.

As regards internal fittings, the savings are gained chiefly from using thin plywood or aluminium plate for filling in the walls of the vehicle, light alloys for the luggage racks, doors and window frames, and steel tubing for the frames of the seats and compartment partitions.

In the case of the buffing and draw-gear, brake fittings, and heating and lighting equipment, the economies effected vary from one country to another. No systematic attemp has been made to lighten the component parts of these items of equipment, now mostly standardised. Some partial savings due to the use of cast steel in place of ordinary cast iron, pressed platework and welding have been obtained.

From the economic point of view, the process of lightening for the most part gives rise to higher costs of construction, from having to use metals which are more expensive in themselves and need specially skilled workers to handle them. The higher cost of material should not, however, be made too much of, as this is partially compensated by the reduced quantity required.

Reducing the weight of passenger rolling stock may be an expensive process in itself, but is nonetheless true that its advantages are such as to justify it. Among these, we may emphasise first and foremost the reduction in haulage costs, which can be put at about one third of the percentage of weight eliminated, and the possiblity of operating trains by locomotives which are less powerful and consequently lighter, less costly and less severe on the permanent way.

In conclusion, since the tubular design of underframe-body offers a maximum degree of ability to withstand both normal and accidental stresses, whilst involving the minimum amount of material in its construction, the safety of the travelling public is in no way affected by reducing the weight of railway rolling stock.

* * *

B. FREIGHT ROLLING STOCK

In this chapter, we shall examine the special characteristics, brought together in Table III, of the various light weight metal wagons that have been brought to our notice, as well as the special measures taken to reduce the dead weight. Under the term metal wagons we include those having wooden sides and roof. Our investigation is restricted to 4 wheel wagons of the three most usual types :

1. Flat open wagons;
2. Hopper wagons;
3. Covered wagons,

which by themselves form almost the entire freight rolling stock of the countries concerned. In addition to the ratio subsisting between the dead weight and the useful load, usually taken as basis for comparison between the various types of wagons, we have brought into Table III the weight per unit of total length, which seems better adapted to bring out the amount of weight really saved. This unitary weight is naturally influenced by the type of wagon and the leading dimensions of the body. In Table IV will be found diagrams of some of the vehicles appearing in Table III.

It should be pointed out that in most countries we are concerned essentially with wagons being built to fill the gaps caused by war operations. As a rule the savings obtained (5 to 15 %) are much less striking than those achiev-

ed in the case of passenger stock, by reason of the very form of the vehicles. Freight rolling stock must in fact be particularly strong to withstand the rough treatment and dynamic stresses it receives during marshalling operations, especially with gravity shunting. It is also absolutely necessary to keep the first cost and upkeep as low as possible, so that it is out of the question to apply the highest and most expensive kind of weight reducing processes. This being the case, the usual course is to use for the essential components normal rolled sections in preference to pressed plate or bent up parts of higher first cost. To avoid increasing the cost of upkeep, the bearings, suspension, and other details are of standard design. As a result appreciable savings in weight have been obtained only on the underframe and body, principally by a more or less general use of welding when assembling.

As Table III shows, the ratio between dead weight and useful load is always less than unity and varies between 0.3 and 0.8 according to the type of wagon. On the other hand, in the case of passenger stock (light weight coaches — Table I), this ratio attains values between 4 and 12, the useful load allowed being some 75 kgr. (165 lb.) per seat. These figures show that reducing the weight offers much greater interest with coaches where the tare is the predominating factor than with wagons. It is to be noted too that the percentage of weight reduction in a wagon, compared with the dead weight, amounts to a small item relatively to the weight of a loaded wagon.

The Belgian National Railways have under consideration a design for a hopper wagon of a load capacity of 25 t. (24.605 Engl. tons) and estimated dead weight of 7.4 t. (7.282 Engl. tons) only. Thanks to an extensive use of light alloys in almost all the components, the saving will be about 30 % compared with a steel vehicle of the same size. The frame, made of pressed plate, has 6 longitudinals, 2 in line with the side walls, 2 in line with the suspension, and 2 inside the frame about 500 mm. (1′ 7$^{11}/_{16}$″) apart. The side walls are made of sheet plate, 5 mm. ($^{13}/_{64}$ inch) thick, pressed into the shape of a diamond point. The sheets are rivetted to the uprights themselves mounted on the outside frame longitudinals. The end walls are formed of a door, consisting of a frame filled in with pressed platework. The sections and sheets are in a light alloy composed of 1.5 % manganese, 5 % magnesium, the rest being aluminium. Tensile strength is 32 kgr./mm² (20.32 Engl. tons per sq. inch) and the elastic limit 18 kgr./mm² (11.43 Engl. tons per sq. inch). The floor is of wood, 45 mm. (1$^{49}/_{64}$″) thick and separated from the framing by protecting strips impregnated with vaseline and talc to resist corrosion The body weighs 3 500 kgr. (7 716 lb.), a reduction of 35 % compared with a normal steel wagon.

The wheel and axle assemblies have light-alloy wheel bodies (5 % copper, 0.3 % magnesium, 0.25 % titan and the rest aluminium), possessing a tensile figure of 35 kgr./mm² (22.22 Engl. tons per sq. inch). The wheels are 1 030 mm. (3′4$^{9}/_{16}$″) dia. and have 80 mm. (3$^{5}/_{32}$″) steel tyres of normal design. A set of wheels with axle weighs 950 kgr. (2 094 lb.). The oil axle boxes in light alloy and steel keep plate weight 30 kgr. (66 lb.) each.

The buffer cylinders and pistons are in light alloy, but to prevent direct friction between these items, the shell has a steel protecting sheath. The brake cylinder and reservoir, in welded steel, form a one piece assembly or unit to which the triple valve is applied. The brake rigging, truss rods and piping are in light alloy. The saving obtained on the brake equipment is about 50 % of the weight.

TABLE III. — **Principal characteristics**

Administration.	*No.*	*Type and series.*	*Number of wagons.*		*Tare.*	*Load.*	*Ratio tare/load.*
			In service.	*Under constr.*	*t.*	*t.*	
Belgian National Railways.	1	Hopper.	...	Project.	7.4	25	0.30
Spanish National Railways.	2	Covered.	...	1 000	11.0	20	0.55
French National Railways.	3	NNTouw flat.	...	1 000	10.4	22	0.47
	4	NNouw flat.	...	500	12.2	20	0.61
	5	TTuw hopper.	...	1 670	10.5	29.5	0.36
	6	TTu hopper.	...	1 250	9.6	30.4	0.32
	7	Fau covered.	...	6 200	12.4	15	0.83
Hungarian State Railways.	8	JZK hopper.	...	2	9.8	20	0.49
Italian State Railways.	9	L hopper (1942).	1 900	...	8.7	22	0.40
	10	L hopper (1945).	...	Not yet known.	9.2	22	0.42
	11	F covered (1942).	4 800	...	10.8	19	0.57
	12	F covered (1945).	...	2 895	11.3	19	0.60
	13	Hg refrigerator.	...	600	16.0	15	1.07
	14	Hgb refrigerator.	...	300	16.0	15	1.07
Netherlands Railways.	15	Flat.	100	400	13.1	17.5	0.75
	16	Hopper.	850	1 900	11.0	20	0.55
	17	Covered.	...	1 200	12.0	20	0.60
Polish State Railways.	18	Wdd hopper.	...	2 000	8.6	23	0.37
Private Swedish Railway Göteborg-Dalarne-Gävle.	19	Flat.	...	100	9.5	25	0.38
Swiss Federal Railways.	20	Flat M^{7}.	350	...	11.2	20	0.56
	21	L^{6} hopper.	369	...	10.5	20	0.52
	22	K^{3} covered.	1 378	...	12.0	15	0.80

of light weight metal wagons.

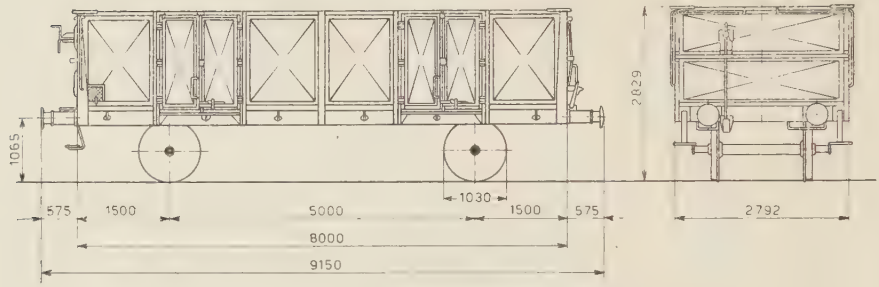
Unit weight per m. of total length kgr./m.	Internal dimensions. Length. m.	Width m.	Height of walls. m.	Floor space. m^2	Capacity m^3	Total length over buffers. m.	Wheelbase. m.	Diameter of wheels. mm.	Remarks.
810	7.99	2.77	1.58	22.1	35	9.15	5.00	1 030	
1 110	8.68	2.80	2.12	24.3	51.7	9.95	6.00	1 006	
1 105	8.18	2.85	0.50	23.3	11.6	9.41	6.00	1 050	Without stanchions.
925	11.95	2.85	0.30	34.0	10.2	13.18	8.00	1 050	
1 180	7.70	2.75	1.72	21.2	36.4	8.89	5.00	1 000	
1 080	7.70	2.75	1.72	21.2	36.4	8.89	5.00	1 000	Without brakegear.
1 110	9.94	2.60	2.12	25.8	59.5	11.18	6.00	1 050	
885	8.82	2.81	1.05	24.8	26	11.08	6.85	1 020	With brakesman's shelter.
1 180	6.37	2.94	1.40	17.5	26	7.38	4.00	1 010	
1 100	6.49	2.85	1.40	18.5	26	8.34	4.00	»	With brakesman's shelter.
1 180	7.90	2.59	2.10	20.4	43	9.18	6.10	»	With brakesman's shelter.
1 145	7.90	2.59	2.10	20.4	43	9.87	6.10	»	
1 740	6.15	2.60	1.90	16.0	30.5	9.18	6.10	»	The load includes 4 m^3 (157.853 cubic feet) of ice.
1 750	6.37	2.29	2.00	14.5	29	9.13	4.50	1 010	
860	13.91	2.75	0.40	38.3	15.3	15.22	9.00	1 000	
1 220	7.79	2.78	1.87	21.6	40.5	9.02	5.00	»	
1 125	9.40	2.74	2.00	25.8	51.6	10.67	6.00	1 000	
925	7.92	2.75	1.55	21.8	33.8	9.30	5.00	1 000	
772	11.00	2.80	0.80	30.8	24.6	12.30	7.00	986	
935	10.20	2.70	0.47	27.5	13	12.0	6.50	1 040	With brakesman's shelter and empty pipes only. (No. 21.)
1 070	7.90	2.70	1.65	21.3	35	9.83	5.00	»	
1 220	8.00	2.71	2.15	21.7	51	9.83	5.00	1 040	Loading limit 18 t. (17.715 Engl. tons).

TABLE IV.

Diagrams of some light weight wagons.

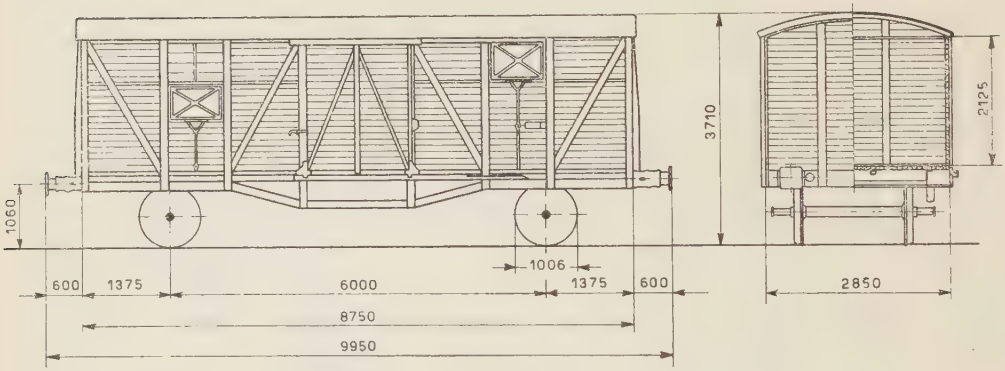
(The numbers correspond with those of Table III.)

Belgian National Railways.



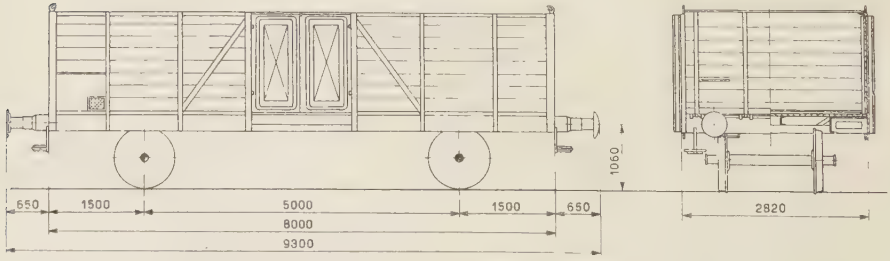
1. Hopper wagon. Tare : 7.4 t. Load : 25 t.

Spanish National Railways.



2. Covered wagon. Tare : 11.0 t. Useful load : 20 t.

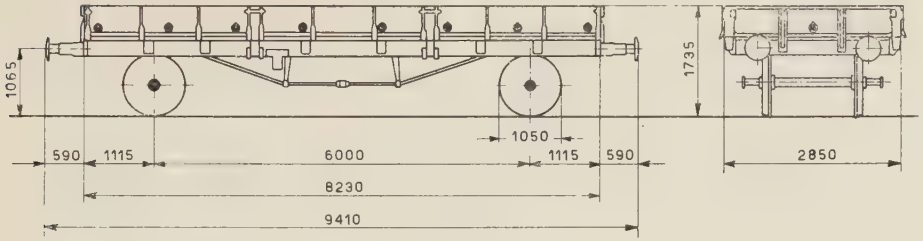
Polish State Railways.



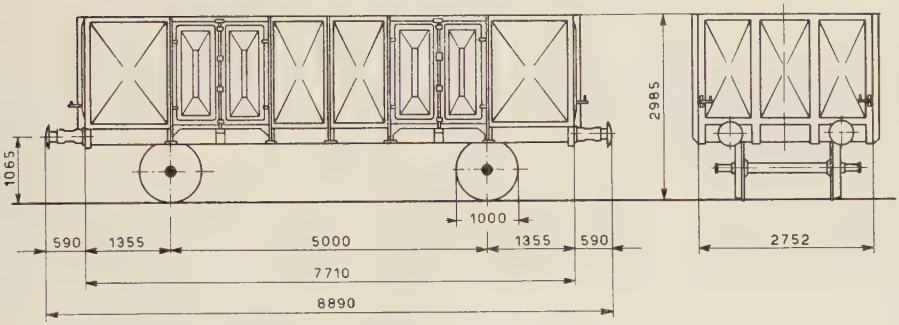
18. Wdd hopper wagon. Tare : 8.6 t. Useful load : 23 t.

TABLE IV. *(Continued.)*

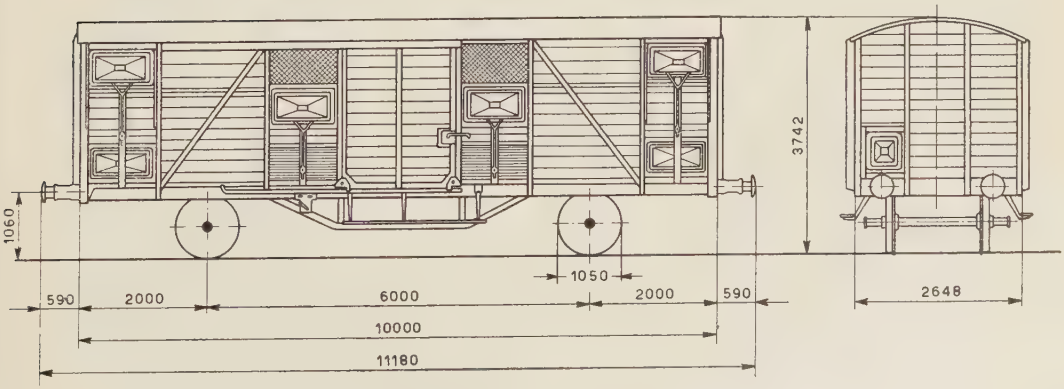
French National Railways.



3. NNTouw flat wagon. Tare : 10.4 t. Useful load : 22 t.



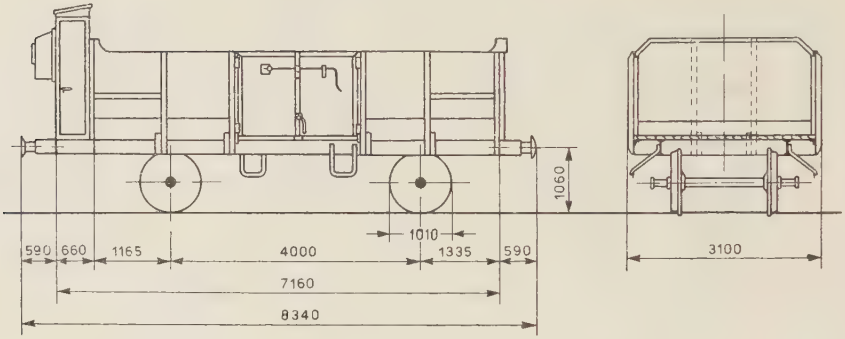
5. TTuw hopper wagon. Tare : 10.5 t. Useful load : 29.5 t.



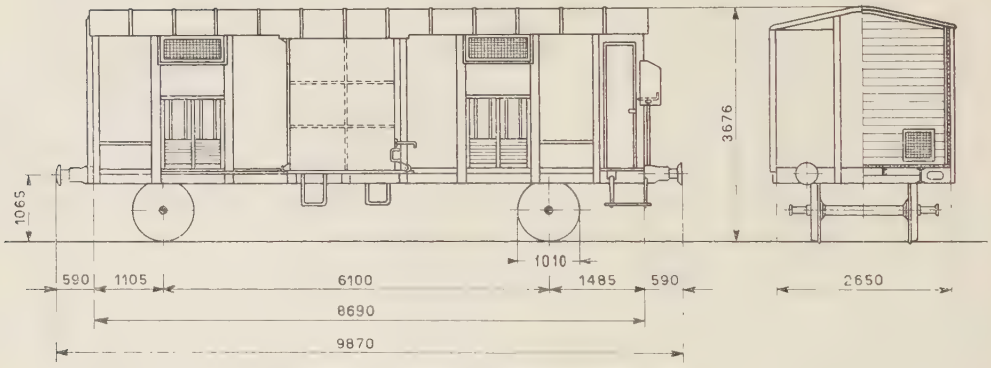
7. Fau covered wagon. Tare : 12.4 t. Useful load : 15 t.

TABLE IV. *(Continued.)*

Italian State Railways.

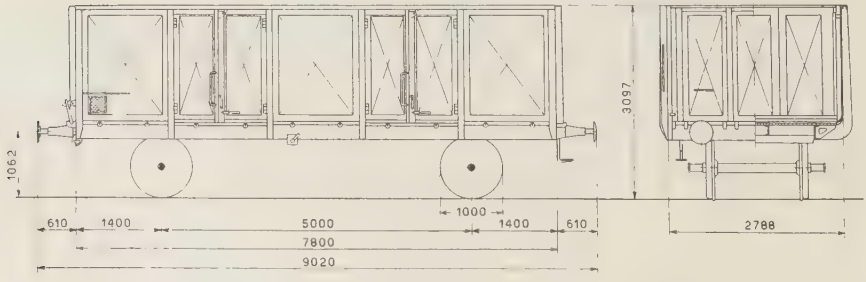


10. L Hopper wagon (1945). Tare : 9.2 t. Useful load : 22 t.



12. F Covered wagon (1945). Tare : 11.3 t. Useful load : 19 t.

Netherlands Railways.



16. Hopper wagon. Tare : 11.0 t. Useful load : 20 t.

The *Spanish National Railways* contemplate ordering 1 000 covered and 500 open wagons with collapsible sides of 11 and 10 t. (10.826 and 9.842 Engl. tons) dead weight respectively, and useful load of 20 t. (19.684 Engl. tons) in both cases. The prototypes of these vehicles are at present being built. The frame comprises two main sole bars each formed of two angles electrically welded to form a U girder of variable height. The framing of the body and roof ribs are formed of plates bent to a half circle with feet so as to reduce the weight. The floor, walls and roof are in thin wood planking. All the components of the underframe and body are arc welded. Rivets have been retained only for parts needing frequent renewal, and in assembling the roof, front and side walls, to facilitate manufacture. The sections and plates are of ordinary mild steel.

The wheels, axles, axle boxes, buffing and drawgear and brake remain unaltered.

Thanks to the efforts made to lighten the underframe and body, it has been possible to lengthen the latter from 6.50 m. to 8.75 m. (21′3$^{15}/_{16}$″ to 28′8$\frac{1}{2}$″) or 35 % without increasing the dead weight.

In France, the *French National Railways* have recently ordered rolling stock of various types, as shown in Table III, of which we shall consider the leading features. These wagons have been designed to conform to the new traffic requirements and progress in technical design. Among the improvements we may mention the standardisation of all components of the framing and the interchangeable items, which allows of building various types of wagons with the same items combined in different ways. This results in noteworthy savings in the supply of materials in construction and upkeep. Finally, we must mention the general use of welding in place of rivetting, giving a very great rigidity to the structure and enabling it to withstand shock whilst reducing the weight. The standard underframes, in normal rolled sections, are equipped at each end with a box form of headstock carrying the drawgear, of high moment of inertia. This box type headstock, formed essentially of the ends of the solebars, the headstock plate proper, the first intermediate cross member and the two buffing struts, makes the end of the frame very rigid, as it is completely welded. The large heavy truss rods attached to the drawgear of the present wagons can thus be replaced by small ones merely joining the headstock to the first cross member. The metal parts of the wagon are in ordinary steel. The floors, walls, and roofs of the covered wagons are of deal or oak planks. A carefully study of the running gear from the point of view of saving of weight and maintenance shows that the present built up wheel body and 65 mm. ($2^{9}/_{16}$″) tyre remains the most economical arrangement. It was decided not to lighten the axle by boring it, the operation being considered too expensive te be justified for freight vehicles. The weight of an axle with wheels 1 050 mm. (3′5$^{11}/_{32}$″) dia. is 1 200 kgr. (2 645 lb.). A certain number of wagons are to have, as an experiment, oil axle boxes with body cover and journal filler piece in light alloy, giving a reduced weight of 59 kgr. (130 lb.). The question of lightening the unsprung items is under investigation. The buffing and drawgear and brake details are also standard and have not been modified.

The following are the details of the types of wagons at present being built :

1. *Flat wagon, series NNTou.* — This is a welded form of the present wagon, the wheelbase being increased to 6 m. (19′8$\frac{1}{4}$″) and the load capacity to 22 t. (21.652 Engl. tons) evenly distributed on the total length. The central strengthening of the frame will allow of its supporting a load of 20 t. (19.684 Engl. tons) over a length of 3.20 m.

(9′10$^{29}/_{32}$″). The dead weight remains as now 10.4 t. (10.235 Engl. tons).

2. *Flat wagon, series NNou.* — This has a 12 m. (39′4½″) underframe carried on two axles with 8 m. (26′3″) wheelbase, and is derived from the existing design, differing only in having collapsible sides, allowing of 20 t. of sand being carried, and the substitution of welding for rivetting. The sides are made of 5 mm. ($^{13}/_{64}$″) plate — 10 mm. ($^{25}/_{64}$″) for the end plates — and flat bars rivetted together. Notwithstanding the savings effected by welding the addition of collapsible sides has increased the dead weight by 500 kgr. (1 102 lb.) bringing it up to 12.2 t. (12.006 Engl. tons).

3. *Hopper wagon, series TTu.* — The method of construction in this case is entirely new. The useful load has been raised from 20 to 29.5 t. (19.684 to 29.034 Engl. tons) thanks to the lightening of certain parts and the adoption of an axle load of 20 t. In addition the height of the body has been increased from 1.41 to 1.72 m. (4′7$^{1}/_{8}$″ to 5′7$^{3}/_{8}$″). Its volume is 36.4 m^3 (1 285.45 cu. ft.). The underframe and body form one piece, all components being welded. The platework is in 3 mm. ($^{1}/_{8}$″) material in the upper and 5 mm. ($^{13}/_{64}$″) in the lower parts, to spread the effects of corrosion more evenly and postpone the need for renewal. To facilitate that operation the plates are rivetted to the vertical members. At the request of the traffic department two double doors are provided in each side wall. A new design of leaf spring had to be adopted to keep the present degree of flexibility with the increased load. To accommodate this spring the solebars have had to be raised and the wheel diameter reduced from 1 050 to 1 000 mm. (3′5$^{11}/_{32}$″ to 3′3$^{3}/_{8}$″). The wheelbase has been increased to 5 m. (16′5″) to keep hunting movements down to the utmost extent possible, and consequently tyre and rail wear. With a deadweight of 10.5 t. (10.334 Engl. tons) for the wagon fitted with the continuous brake, the deadweight per tonne carried comes to 356 kgr. (784 lb.) instead of 485 kgr. (1 069 lb.) for the existing type, a 26 % saving. As an experiment 1 000 wagons are to have walls of 4 mm. ($^{5}/_{32}$″) in aluminium alloy of 30 kgr./mm^2 (19.05 Engl. tons per sq. in.) tensile and 20 % elongation, giving a further saving of 500 kgr. (1 102 lb.) per wagon.

4. *Covered wagon, series Fau.* — This wagon, carrying 15 t. (14.763 Engl. tons) has been kept to all intents and purposes as at present with all its characteristics, its components being however standardised and welding used for assembly. Heat insulation is provided by a double wood plank roof, with air space between. The sliding doors are formed of a frame of welded section panelled in wood. A trial is to be made of light alloy framing and aluminium panelling.

The French National Railways have built a prototype hopper wagon with all underframe and body components, brake gear, buffers, and wheel centres in light alloy. This wagon has the same dimensions as the present one. Dead weight has been cut down from 9.8 to 6.5 t. (9.644 to 6.397 Engl. tons) and useful load increased from 20 to 25 t. (19.684 to 24.605 Engl. tons). The tare to load ratio is thus 0.26, about half that of the normal steel wagon. This prototype, which has been in service for several months, is intended to demonstrate the possibility of using light metals in this class of work and their behaviour under normal service conditions. It will also be possible to see whether the increase in the purchase price consequent on the very wide use of light alloys is justified by economies in running.

The *Hungarian State Railways* have all-metal hopper wagons under construction as prototypes from the weight reduction point of view, the saving being obtained by using aluminium alloys for the brakesman's shelter, the walls and floor. The underframe is in ordinary steel section, welded and insulated from the floor by bituminised canvas filling. The side walls are made of 5 mm. sheet, bent to a U at the ends, rivetted to each other by a lap joint and so forming a vertical member. The useful load is 20 t. and the dead weight 9.8 t. (9.644 Engl. tons), a saving of about 2 t. (1.968 Engl. tons) or 17 %.

The *Italian State Railways* have put into service in recent years a consider-

able number of hopper and covered wagons of light design (Nos. 9 and 11 in Table III). Thanks to good detailed design work and use of welding, especially in building up the underframe, it has been possible to get the dead weight down by an average of 10 %, the fundamental characteristics of the vehicle remaining unaltered.

The end and side walls of the hopper wagon are in 3 mm. plate, 42 kgr./mm² (26.67 Engl. tons per sq. inch) tensile, rivetted to the uprights. The body and roof of the covered wagon are in 1.5 mm. (0.059 inch) and 1 mm. (0.0393 inch) plate and likewise rivetted to the uprights and roof ribs, but they are duplicated inside by thin wood panelling, 23 mm. ($^{29}/_{32}$″) for the side walls. The bodies of these wagons weigh respectively 2 280 and 3 570 kgr. (5 026 and 7 870 lb.), a reduction of 5 %. Fig. 58 shows a covered wagon 1942 type; the mean dead weight is 10.8 t. (10.629 Engl. tons) for a 19 t. (18.699 Engl. tons) load.

The hopper and covered wagons of the 1945 type (diagrams 10 and 12) now being built only differ from the above in having a brakesman's shelter for the hand brake which increases the length and of course the weight. The wagons shown in Fig. 57 are able to run at 75 km. (46 miles)/h. and the covered ones at 120 km. (74 miles)/h.

The running gear, buffing and drawgear are unaltered. A 15 % saving in weight has been achieved in the brake equipment by using welded steel cylinders and reservoirs.

The *Netherlands Railways* in 1938 put into service a hundred 17.5 t. (17.223 Engl. tons) flat wagons and eight hundred and fifty 20 t. (19.684 Engl. tons) hopper wagons, of 13.1 and 11 t. (12.892 and 10.826 Engl. tons) tare respectively. They are of all-metal construction, the floors alone being of wood. The extensive use of welding enabled weight to be cut down and load capacity increased.

In the hopper wagon the walls are 4 mm. ($^{5}/_{32}$″) copper-steel, to limit the effects of corrosion. They are strengthened at the upper part throughout their length by a U section rib. The uprights are of special form — seen in Fig. 59 — of 6 to 8 mm. ($^{15}/_{64}$″ to $^{5}/_{16}$″) welded plates forming a double T section of variable height. The dead weight is pratically the same as for the wooden wagon while its capacity has been increased from 35 to 40.5 m³ (1 236 to 1 430 cu. ft.) by increasing the height of the walls. The construction and volume of the body however are such as to be able to take a useful load of 30 t. (29.526 Engl. tons) in the future.

In the covered wagons the walls are still made of planks, 25 mm. (1″) thick, bolted to the uprights. The roof is of metal, consisting of two steel plates; the outer is 1.5 mm. (0.059 inch), the inner 1 mm. (0.0393 inch) thick, separated by a 52 mm. ($2^{1}/_{16}$″) air space. The double sliding doors are of 2 mm. ($^{5}/_{64}$″) pressed plate, strengthened by rolled section ribs. The dead weight is 12 t. (11.810 Engl. tons), a saving of 600 kgr. (1 322 lb.) compared with the 1930 wagon. The wheelbase is now 6 m. (19′ $8^{1}/_{4}$″) instead of 5.5 m. ($18^{\prime\prime 11}/_{16}$″) and the useful load 20 instead of 17.5 tonnes, a considerable improvement in the load/tare ratio.

Wheels and axles are of normal type, with roller bearings to diminish frictional resistance. Buffing and drawgear and brake equipment have not been lightened.

The *Polish State Railways* are building 2 000 hopper wagons (diagram 18) capable of transporting 25 t. (24.605 Engl. tons) and weighing 8.6 t. (8.463 Engl. tons) empty or 800 kgr. (1 764 lb.) less than the present wagons. The reduction in weight has been obtained by using welding for the underframe and

Italian State Railways.

57. Type L hopper wagon (1945). Capacity : 26 m³ (918 cu. ft.). Tare : 9.2 t.

58. Type F covered wagon (1942). Capacity : 43 m³ (1 518 cu. ft.). Tare : 10.8 t.

Netherlands Railways.

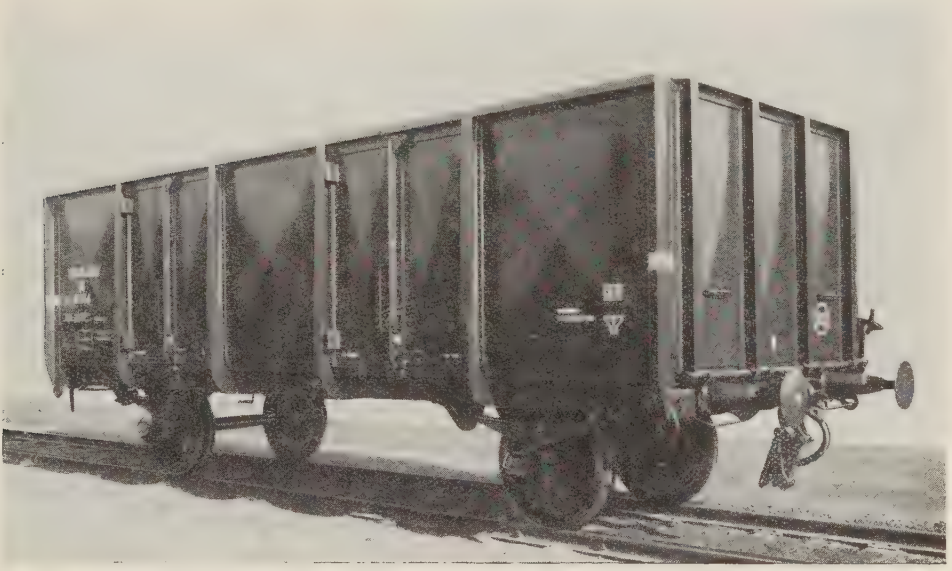


Fig. 59. Hopper wagon. Capacity : 40.5 m³ (1 430 cu. ft.). Tare : 9.9. t. (without brake gear).

Göteborg-Dalarne-Gävle Railway (Sweden).

Fig. 60. — All-metal flat wagon. Tare : 9.5 t.

Swiss Federal Railways.

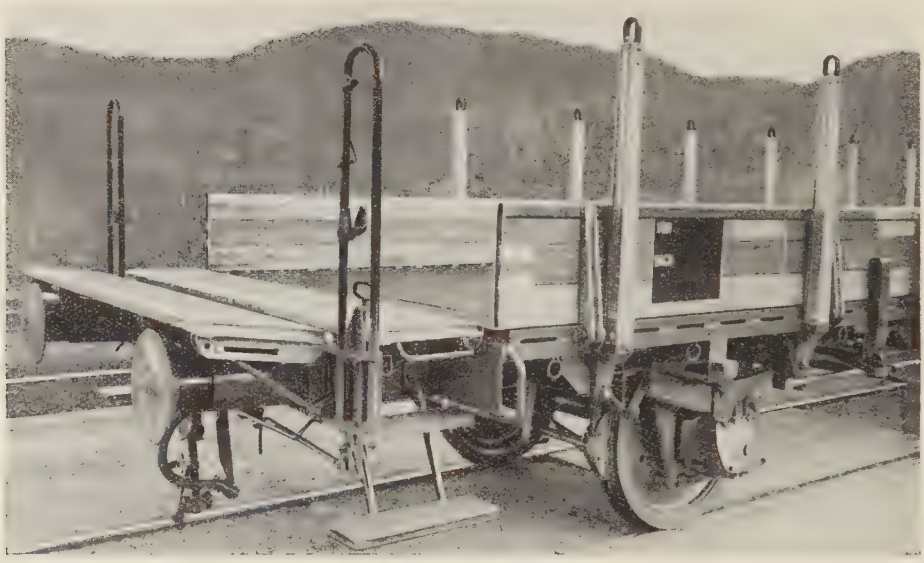


Fig. 61. — Series M[7] flat wagon with walls and stanchions of light alloy. Tare : 11.1 t.

Fig. 62. — Series L[6] hopper wagon. Capacity : 35 m³ (1 236 cu. ft.). Tare : 10.5 t.

body frame. The walls and floor are of deal, the door in pressed platework.

The *Göteborg-Dalarne-Gävle Railway* in Sweden is having built 100 all-welded hopper wagons, of 9.5 t. (9.349 Engl. tons) dead weight (formerly 11.2 t. [11.022 Engl. tons]), a saving of 1.7 t. (1.672 Engl. tons) or 15 %, the result of using welded pressed plate for the underframe solebars and the walls (Fig. 60).

The *Swiss Federal Railways* have during the last 10 years put into service the wagons shown in Table III, without making any special effort to lighten the design. They have taken advantage of the benefits of welding to strengthen the underframe without increasing the dead weight. The three types of wagons, the design of which is now standardised, are the following :

1. *Flat wagon* with collapsible walls, and hinged stanchions, able to carry 20 t. (19.684 Engl. tons). Mean deadweight is 11.2 t. (11.022 Engl. t.).

2. *Hopper wagon* (Fig. 62) with wooden walls and steel doors ; load 20 t. and dead weight 10.5 t. (10.334 Engl. tons).

3. *Covered wagon*, 51 m³ (1 811 cu. ft.) capacity (Fig. 63), with wooden walls and roof in 2 mm. ($^5/_{64}$″) welded steel plate, attached directly to the ribs of U section. Useful load normally is 15 t. (14.763 Engl. tons) but can amount to 18 t. (17.715 Engl. tons). Mean dead weight is 12 t. (11.810 Engl. tons).

Swiss Federal Railways.

Fig. 63. — Series K³ covered wagon. Capacity : 51 m³ (1 811 cu. ft.). Tare : 12 t. Door and buffers of light alloy.

We wish to make special mention of certain devices which lead to a saving in weight, some of which have only been tried experimentally so far on a few vehicles.

Some 30 flat wagons (Fig. 61) have collapsible sides and hinged stanchions

welded frame, itself forming a lightened type of construction. In service for three years, the wagons have proved entirely satisfactory.

The doors of the hopper wagons (Fig. 62) are in 5 mm. ($^{13}/_{64}$") mild steel plate, surrounded and strengthened by U shaped platework, welded to the main sheet-

Swiss Federal Railways.

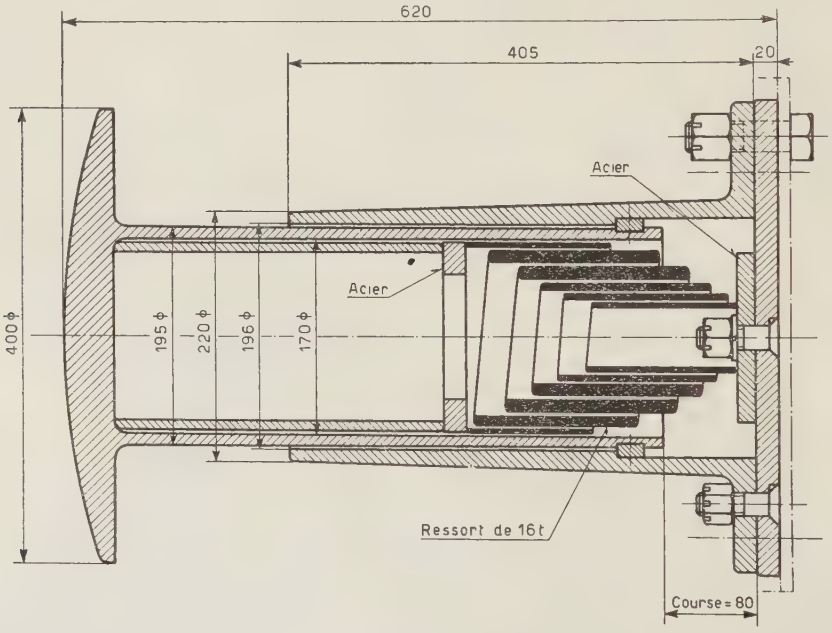


Fig. 64. — Light alloy buffer. Weight 60 kgr. (132 lb.).

Explanation of French terms:
Acier = Steel. — Ressort de 16 t. = 16 t. spring. — Course = Stroke.

in hard anticorodal alloy. The side walls, divided into four equal parts, and the end walls are each formed of 3 components of hollow cross section, joined together by a dovetail fitting and bolted to the uprights. These walls are 55 mm. ($2^{3}/_{16}$") thick and 475 mm. ($1'6^{45}/_{64}$") high. The dead weight has not fallen appreciably compared with the present design where the walls are of planks surrounded by a pressed sheet steel

ing. The brakesman's shelter is of rolled section steel framing with sheet steel panels welded together.

The sliding door of the covered wagons (Fig. 63) are in aluminium alloy sections and sheet, rivetted. Their weight is about half that of the steel type, saving 150 kgr. (330 lb.) per wagon. This reduction in weight aimed at facilitating the working of the doors. Some 100 wagons have plunger type buf-

fers entirely in light alloy, only the springs and the two stops are in steel (Fig. 64). The casing and buffer itself are formed up when hot at very high pressures, which produces such smooth surfaces that no machining is required. A buffer weighs about 60 kgr. (132 lb.), a saving of 280 kgr. (617 lb.) per wagon.

Swiss Federal Railways.

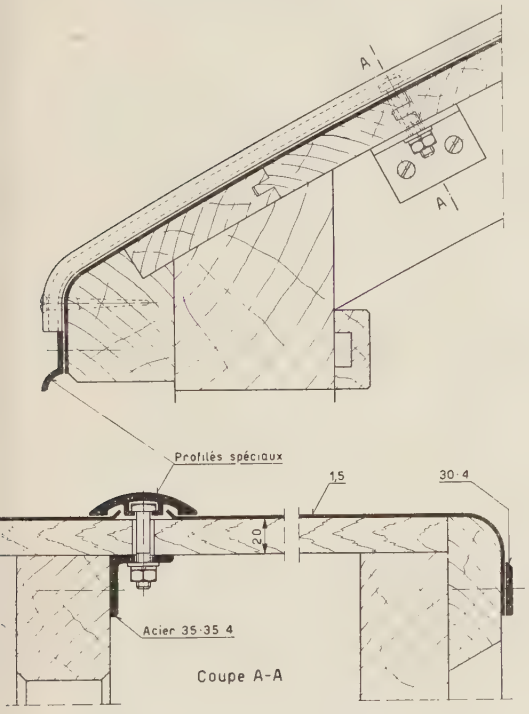


Fig. 65. — Details of roof construction in aluminium alloy.

Explanation of French terms :

Profilés spéciaux = Speçial sections.
Acier = Steel.
Coupe A-A = Section through A-A

The Swiss Federal Railways have also used aluminium alloy for the roofing of their covered wagons. They have tried different designs, of which we will mention that seen in Fig. 65, which appears to give the best results from the point of view of robust design and ease of manufacture. This design, used also for coaches and the wooden roofed wagons, is destined to replace the use of impregnated canvas, the upkeep of which is too costly.

Summing up, we note that there is relatively little light-weight freight stock in service at present, but that a reduction of weight is contemplated by different railways for wagons now being built or being designed. It involves essentially the underframe and in certain circumstances the framework of the body. Welding, and here and there the use of light alloys, are the means resorted to in endeavouring to bring the weight of freight rolling stock down.

* * *

We wish to end our report by thanking all the Managements who helped us by replying to our questionnaire so fully. We also wish to thank the two Swiss firms building rolling stock for the abundant information and photographs with which they were good enough to supply us.

[625 .2 & 669]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

14th. SESSION (LUCERNE, 1947).

QUESTION II.

Lightening the rolling stock.

Reduction in the weight of rolling stock (passenger and goods) by :

a) choice of the method of construction;

b) use of special steels;

c) use of alloys.

REPORT

(Light Railways and Colonial Railways of all countries),

by W. A. VRIELYNCK,

Ingénieur civil, Directeur du Service de la Traction et du Matériel de la Société Nationale des Chemins de fer Vicinaux (Belgium).

Up to the time of writing, 14 replies have been received to the questionnaire which was sent out.

All were negative in the sense that not one of the companies in question had built nor designed light-weight rolling stock.

The following companies did not give any explanation whatsoever regarding this matter :

Compagnie belge de chemins de fer et d'entreprises.

Société générale des chemins de fer économiques, à Paris.

Compagnie française des chemins de fer de l'Indochine et du Yunnan.

Société du chemin de fer de Damas-Hama et prolongements.

Chemins de fer économiques du Nord (France).

Chemins de fer du Togo.

Societa per Azioni Torinese Tramvie Intercommunali.

The « Compagnie des chemins de fer du Congo supérieur aux Grands-Lacs africains » states that they are not interested in the question as they anticipate using air transport.

The « Société du chemin de fer Congo-Océan » (Congo-Ocean Railway Company) does not propose to build light-weight rolling stock as they are not equipped for the purpose.

The « Compagnie des chemins de fer du Maroc » and the « Chemin de fer de l'Indochine » are shortly commencing design on the lines suggested by the projects of the S.N.C.F. (French National Railways).

The « Chemins de fer de Dakar-Thiès-Toukoto » have given up the idea of

anything of this sort owing to the state of the tracks.

The « Compagnie du chemin de fer franco-éthiopien » from Djibouti to Addis-Abeba and the « Office des Transports Coloniaux » (OTRACO) of Brussels have under consideration the building of light-weight rolling stock, but have not yet commenced any design on this subject.

We will, therefore, confine ourselves to setting out what the « Société Nationale des Chemins de fer vicinaux belges » (S.N.C.V.) has done and is planning in this field.

The cars actually built and projected will be compared with those of the Zurich Municipal Tramways, the President's Conference Committee of the U.S.A. (P.C.C.) and the Lille-Roubaix-Tourcoing (E.L.R.T.), and we will try to draw some conclusions from these experiences. (*)

Electrical system of the Belgian Light Railways (S. N. C. V.).

The Belgian Light Railways system consists of approximately 4 800 km. (2 982 miles) of track, 1 500 km. (932 miles) of which are electrified.

The greater part of the electrified lines are of an inter-town character. Because of the very dense population served, this type of light railway has more the character of a tram than a railway system.

In some cases they are laid out on separate track beds, but the tracks are usually on the side of the road or actually incorporated in the roadway.

It is, in effect, a tram which runs on busy town roads carrying passengers to other neighbouring towns or to the residential areas of the suburbs. For two or three kilometres, the tram stops every 300 m. (328 yards) and has to contend with all the difficulties of town traffic, but after this, speed is increased, and stops only occur every 1 000 m. (1 094 yards).

At the beginning of the century, the service was carried out by four-wheeled vehicles. The wheelbase varied through the years between 1.80 m. (5′10⁷/₈″) and 3.20 m. (10′6″). Since 1930, bogie coaches have been used, and since 1936, steel bodies. These coaches have given entire satisfaction, and large numbers have been built during the past few years. They weigh 20.5 tonnes (20.176 Engl. tons) and the trailers approximately 10.5 tonnes (10.334 Engl. tons).

Town systems and their rolling stock.

Certain lines of the Belgian Light Railways system (approximately 30) are of an exclusively town character, and are no different whatsoever from other tramway systems which run through our towns. Journeys are short, and many passengers board and alight at every stop. The traffic is very frequent and the maximum and average speeds are relatively low. The tracks are curved, with curves of small radius. It is important therefore, that little time is lost at the stops so that as many passengers are carried as possible, and that the overloading of the route is reduced to the minimum.

The vehicles best adapted to this type of traffic must have bogies, large platforms, relatively few seats, and large exits. They must also work without trailers.

At the present time, this traffic is chiefly carried out by four-wheeled rail cars. As this stock was not very well

(*) We would like to draw attention here to a paper written by our Engineer, Monsieur Joseph DAUBRESSE on the question of « Safety and Lightening of Rolling Stock » which appeared in No. 1 of 1944 of the *Bulletin technique de l'Union des Ingénieurs de Louvain*. His conclusions have been incorporated in our lightened prototype coaches.

adapted to the service, just before the war, the Belgian Light Railways Company built in their Brussels workshop a rail car which embodies as far as possible the desiderata mentioned above.

In the design of this new type of vehicle, we have endeavoured to facilitate maintenance and repair and to lighten the construction. Having had a good number of motor bogies damaged by the penetration of snow and damp during two or three very severe winters, we have tried to raise the motors and to enable this to be done, 2 motors only have been fitted per vehicle along the centre line, suspended from the body and driving the axles by means of cardan shaft and worm and worm wheel.

Owing to the above, the lightening was only a secondary object in the design which would have as a result the reduction in the cost of the vehicle, lessen the consumption of energy, as well as the wear on the rails and wheels.

After two prototypes of lightweight town type coaches in steel had been built, two other similar prototypes, but in lightweight metal, were constructed.

Rolling stock of inter-town systems.

The results obtained being satisfactory, the design of the lightened construction trailers and bogie rail cars for inter-town working was put in hand. These latter are now being built. It being necessary that they should draw one or two trailers, and be used as trains capable of carrying more than 250 passengers over gradients up to 60 mm. ($2^{23}/_{64}$") or even 80 mm. ($3^{5}/_{32}$") per metre, at the same time attaining an average speed of 30 km. (19 miles) p.h., it appeared impossible to reduce the tare of the motor coach to less than 18 tonnes (17.715 Engl. tons) adhesive weight. So steel was used in the construction.

For the trailer car, on the other hand, we were not restricted by the foregoing considerations in the lightening of this vehicle. It was only necessary to bear in mind resistance to overloading and collisions, together with stability and comfort.

Lightening of vehicles.

When studying the question of lightening rolling stock, the material to be used, the shape to be adopted and the arrangement of the details are considered.

Originally, the material considered was ordinary mild steel. Special steels were disregarded owing to assembling and welding difficulties, and the same remark applies to the lightweight materials with aluminium or magnesium base, owing to their high cost, the difficulty at that time of obtaining them, and the necessity of rivetted construction which must be heavier than welding. Owing to the reduced modulus of elasticity of these lightweight materials, it was feared that it might be necessary to increase the thickness of the section to such an extent in order to maintain the rigidity of the whole car that the gain in weight would be nullified. The lightweight materials were also not favoured owing to their weak resistance to alternating stresses and low figure of elasticity.

At the commencement, therefore, recourse was made to easily weldable ordinary mild steel, and research was confined to the maximum utilisation of this material.

Bearing in mind the principle that « all mass of material which is not uti- » lised to the maximum reduces the » capacity for work and lowers the » resistance to shock », endeavour was made to design shapes of equal resistance in which all portions were subjected to as uniform stress as possible.

It was then necessary to determine carefully and make exact calculations of

the details which would be required to support the loads.

The *principal directions* of our studies in regard to lightening were the following :

1) Utilisation of the body framework to carry out part of the function usually performed by the underframe only.

To enable this to be done, the solebars, body pillars, transoms and framework were all made as components of the trellis girder. This was facilitated by the arrangement chosen for the movable windows which opened by lowering their upper portion and did not necessitate the provision of slides in the casing. The diagonals, which stiffen the framework, were able to be placed in their width with a minimum weight of material.

2) Arrange the principal bogie details in such a manner that they give the best sections for the moment of inertia relative to the weight of the metal by means of fabricated construction of rolled details assembled by arc welding.

3) Arrange the brake rigging so as to prevent secondary forces (no bayonet joints in the levers and suppression of the counter-shafts).

4) Lighten as much as possible the

TABLE

	1	*2*	*3*	*4*	*5*	*6*
	S.N.C.V. *4-wheeled rail car.*	S.N.C.V. *Steel town type bogie rail car. (2 prototypes already built.)*	S.N.C.V. *Light-weight metal town type bogie rail car. (2 prototypes already built.)*	ZURICH. *Light-weight metal town type bogie rail car, 401 class.*	P.C.C. *Bogie rail car, town type.*	E.L.R.T. of Lille *Town type bogie rail car (being designed).*
Track gauge, m.	1.000	1.000	1.000	1.000	1.435	1.000
Width of body, m.	2.200	2.200	2.200	2.200	2.540	2.200
Total length over body, m.	9.520	12.000	12.000	13.200	14.000	13.000
Total length over buffers, m.	10.446	13.000	13.000	13.735	14.020	13.350
Height of body floor, m.	0.810	0.820	0.820	0.780	0.810	0.730
Height of platform floor, m.	0.714	0.740	0.740	0.780	0.810	0.730
Height of 1st footstep, m.	0.385	0.390	0.390	0.320-0.605	0.37-0.59	0.415
Weight empty, t.	14.6	13.8	10.8	13.5	15.7	15.5
Area of platforms, m^2	4.6	9.6	9.6	8.2	9	6.5
Number of seats	24	24	24	27	55	28
Number standing	42	86	86	73	80	62
Tare weight per seat, kgr.	608	585	450	500	285	500
Tare weight per passenger, kgr.	220	125	98	135	117	175
Unsuspended weight, kgr.	2 200	...	1 880	1 000	...	3 100
Distance between bogie centres, m.	...	6.00	6.00	6.40	6.93	6.50
Bogie wheel base, m.	...	1.80	1.80	1.625	1.90	1.65
Weight of bogie with motors, kgr.	...	...	...	3 000	3 300	3 250
Weight of bogie without motors, kgr.	...	1 700	1 700	2 400	2 650	2 130
Motors, H.P. at 1 hour rating	2 × 68	2 × 66	2 × 66	4 × 60	4 × 55	4 × 50
Motor speed, r.p.m.	760	1 100	1 100	1 100	1 670	...
H.P. per tonne empty	9.3	9.5	12.2	17.8	14	13

electrical equipment and accessories (hand rails, seats, etc.).

In our resistance calculations, the underframe and body form one combined unit. This latter is not considered as a completely closed tube. The sheeting does not intervene as an element of resistance.

In addition to acting as support, the body framework must also protect passengers in case of collisions. In this connection, a comparison is drawn with heavy weight rolling stock in service, and it is ensured that sections of the body framing shall not be more liable to deformation than those of corresponding details in the old type construction.

TABLES.

We have shown, in the form of tables, comparisons between the various types of vehicles built in Switzerland, America, France and Belgium.

Columns 1 to 6 of Table No. I give the principal characteristics of the various rail cars which work singly on specifically town systems.

Columns 7 and 8 show respectively characteristics of our bogie rail cars for intertown services of the heavy and

I.

7	8	9	10	11	12	13	14	15
S.N.C.V. *Heavy-type bogie inter-town rail car.*	S.N.C.V. *Lightened type inter-town bogie rail car (being designed).*	ZURICH. *Inter-town bogie type rail car, 351 class.*	S.N.C.V. *Bogie trailer coach.*	S.N.C.V. *Lightened type bogie trailer coach (being designed).*	ZURICH. *Light-weight metal bogie trailer coach, 711 class.*	S.N.C.V. *4-wheeled heavy oil rail car.*	S.N.C.V. *Old-type heavy oil bogie rail car.*	S.N.C.V. *New-type heavy oil bogie rail car.*
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.400
12.300	13.200	13.200	12.975	13.200	13.330	8.600	12.300	14.800
13.420	14.100	13.950	14.015	14.100	13.780	9.540	13.340	15.450
0.835	0.848	0.900	0.836	0.848	0.780	0.918	1.000	1.020
0.766	0.670	0.900	0.767	0.670	0.780	0.738	0.763	0.790
0.415	0.360	0.350-0.670	0.408	0.360	0.320-0.605	0.365	0.415	0.385
20.5	18.0	17.5	10.5	8.5	9.0	11.1	19.3	18.5
5.3	4.7	8.2	6.0	5.5	9.3	3.8	5.25	5.25
30	36	27	36	36	21	24	30	52
48	43	73	54	50	84	36	48	48
682	500	650	290	235	430	417	643	360
260	230	175	115	100	86	185	245	185
4 000	2 200	1 200	1 600	1 600	800	1 800	2 900	3 200
6.20	6.70	6.40	6.80	6.70	6.68	...	6.20	8.00
1.90	1.65	1.70	1.60	1.60	1.70	...	1.70	1.70
4 250	...	3 800	...	...	...	...	...	...
2 500	2 100	2 400	1 700	1 500	...	...	3 075	2 850
4 × 66	4 × 75	4 × 85	...	...	...	120	130	180
1 100	...	...	...	...	...	...	...	1 500
12.8	16.6	19.4	...	...	...	10.8	6.2	9.8

	S.N.C.V. *Heavy type bogie rail car.*	S.N.C.V. *Light type town bogie rail car.*	S.N.C.V. *Lightened type, intertown bogie rail car (being designed).*
Bogie	Single cast steel block.	Mild steel plates and sections assembled by electric arc welding.	
Wheels	Spoke.	Spoke.	Disc.
Axles	Solid steel axles Ni-Cr or Ni-Mn or Ni-Cr-Mo. — Re = 76 kgr./mm² — Rr = 95-100 kgr./mm² — A = 12 %. Impact resistance = 13 kgr./cm².		
Axleboxes	S.K.F. type with two sets of cylindrical type roller bearings.		S.K.F. type with two sets of spherical roller bearings.
Drive	Straight gears.	Worm and worm-wheel — cardan shafts.	
Motor suspension	On the axles.	(Silentbloc) to the body.	
Centre line of motors	Transverse.	Longitudinal.	
Underframe	Pressed steel details assembled by electric arc welding.	Light metal details (Almg-5), sections ⊏ L and — assembled by light metal rivets.	Rolled steel details (sections ⊏, L and —) assembled by rivets.
Body framework	Pressed steel details, section ⊏, and L, electrically arc welded. Sheets covering the casing assist in reducing the shearing strains. The slides arranged in the casing allow the movable windows to be lowered.	Details in Almg-5, sections ⊏, L and — assembled by rivets. The diagonals in the casing assist in reducing the shearing strains. The upper portion of the movable windows work in the slides arranged in the upper ribs.	Rolled steel details, sections ⊏, L and —, assembled by electric welding. The diagonals arranged in the casing assist in reducing the shearing strains.
Exterior sheeting	Copper steel 2 mm.	Almg-2 1.5 mm.	Almg-2 2 mm.

ZURICH. *Light type town bogie rail car.*	ZURICH. *Lightened type inter-town bogie rail car.*	E.L.R.T. (Lille). *Light type town bogie rail car (being designed).*	P.C.C. (U.S.A.). *Light type town bogie rail car.*
Brown-Boveri Simplex type.	Brown-Boveri Simplex type or similar.	Single cast steelblock, without welding.	Steel sections and cast steel details assembled by arc welding.
With rubber details.		Disc.	With rubber details.
Hollow axles. Re = 41 kgr./mm² — Rr = 70 kgr./mm² — A = 23 %.		Solid steel axles with 2 % nickel. R = 58 — A = 20 %.	Solid axles.
Spherical or cylindrical roller bearings.		...	Cylindrical roller bearings.
Straight gears and rubber discs or strips.		Straight gears.	Conical gears.
Fixed to a block in the middle of the bogie; bearing by means of laminated springs on the axleboxes.		On the axles.	Fixed to a cradle suspended on the bogie frame.
Transverse.		Transverse.	Longitudinal.
Steel sheets electrically arc welded.		Two steel solebars joined to the right of the bogies by two cast steel cross-pieces and here and there by cross pieces in welded plate. Floor 10 mm. aluman sheeting rivetted to the solebars on the 50 angle irons.	Pressed details electrically arc welded.
Rivetted details of anticorodal.	Rolled steel details electrically arc welded.	Parallelepiped wood details without tenons or morticing, assembled by bolts having a dia. of 8 mm. at most.	Pressed details electrically arc welded.
Aluman 2 mm.	Steel. Type 37. 2 mm.	Duralinox 320.	Copper steel sheets electrically spot welded.

	S.N.C.V. *Heavy type bogie rail car.*	S.N.C.V. *Light type town bogie rail car.*	S.N.C.V. *Lightened type inter-town bogie rail car (being designed).*
Outside doors	Aluminium. Single sliding worked by hand.	Wood pillars reinforced by steel. Double sliding, worked by hand.	Double folding.
Inside partition . . .	3 complete partitions of steel covered with wood.	3 complete partitions, framework wood covered in Almg-2 sheeting.	Nil.
Ceiling	Aluminium sheet 1.5 mm.	Aluminium sheet 1 mm.	Plywood or unalit (compressed cardboard).
Interior panelling . . .	Moulmein plywood.	Strong cardboard.	Unalit (compressed cardboard).
Buffing drawgear . . .	Buffer-beam with 2 buffers (volute springs hooks and screw coupling).	Beam resting on central buffer (volute springs) and screw coupling.	
Position of driver . . .	2 standing.	2 standing.	2 standing or seated.
Controllers	2 cam-type controllers.		
Automatic starting gear.	No.	No.	No.
Brakes	— Rheostat (emergency). — Hand. — Direct and automatic compressed air (service).	— Hand. — Direct compressed air (service).	— Rheostat (service). — Hand. — Direct and automatic compressed air (service).
Reduction of vibration .	Nil.	Motors suspended on the body by four silent-blocs.	— Motors suspended on the body by four silent-blocs. — Spring supports of the bolster truck interposed with wooden or hard rubber blocks. — A trial of rubber-tyred wheels — Body sheeting sprayed with asbestos.

II. *(Continued.)*

ZURICH. *Light type town bogie rail car.*	ZURICH. *Lightened type inter-town bogie rail car.*	E.L.R.T. (Lille). *Light type town bogie rail car (being designed).*	(U.S.A.). P.C.C. *Ligt type town bogie rail car.*
Double folding with folding footsteps.		Double folding with folding footsteps.	Double folding with interior footsteps.
Nil.	Nil.	Nil.	Nil.
Paratex (compressed cardboard) painted white.		3 mm. plywood.	Masonite (compressed cardboard).
Aluminium sheets covered in blue-grey linoleum.		Pegamoid on Duralinox 320 of 2 mm.	Masonite (compressed cardboard).
Semi-automatic coupling gear (Fischer, Schaffhouse).		Bell-mouthed coupling of steel with 3 links.	No coupling, gear hydraulic buffers.
One seated.	One standing or seated.	One seated.	One seated.
Electro-pneumatic and electro-magnetic contact by means of pedal.	Electro-pneumatic contact governed by manipulator.		...
No.	No.	No.	Yes.
— Rheostat (service). — Hand. — Compressed air (safety stop). — Electro-magnetic on the rails (emergency).		— Rheostat (service). — Hand. — Compressed air (stop). — Electro-magnetic on the rails (emergency).	— Rheostat (service). — Solenoid working on the drum of the motor shaft (service). — Electro-magnetic on the rails (emergency).
— Laminated bogie springs. — Rubber-tyred wheels of the S.A.B. type. — Body sheeting covered by cardboard or sprayed with asbestos. — Use of silent-blocs.		— Suspension of the compressor by silent-blocs. — Trial of rubber-tyred wheels.	— Suspension by means of conical rubber springs. — Rubber-tyred wheels (180 kgr. of rubber).

lightened types (under construction), both of steel.

Column 9 relates to a Swiss rail car (Zurich Class 351), which has to carry out a somewhat different service, but nevertheless comparable.

Column 10 relates to the trailer bogie cars of the Belgian Light Railways (S.N.C.V.) of the present type, built of steel; Column 11 a bogie trailer of the Belgian Light Railways in light weight metal, which is being designed; Column 12 a light weight metal bogie trailer, Class 711, of the Zurich Tramways, and Columns 13, 14 and 15 to heavy oil rail cars which work on our non-electrified lines.

Table II notes the peculiarities of construction of the rail cars and Table III those of the trailers.

Table IV gives an analysis of some of the weights of the bogie rail cars of the Belgian Light Railways.

Analysis of lightened details.

The principal details which have brought about the lightening of our rolling stock are the following :

bogies,

body framework,

TABLE III.

	S.N.C.V. *Standard type bogie trailer.*	S.N.C.V. *Lightened type bogie trailer (being designed).*	ZURICH. *Lightened type bogie trailer.*
Bogie	Rolled and pressed steel details, assembled by electric arc welding.	Mild steel plates and sections assembled by electric arc welding.	Steel plates and sections assembled by electric arc welding.
Underframe . .	Pressed steel details assembled by electric arc welding.	Light-weight metal details (Almg-5), sections ⊏, L and —, assembled by light-weight metal rivets.	Rivetted anti-corodal sheets partially reinforced by steel sheets.
Body framework .	Pressed steel details, sections ⊏ and L electrically arc welded (as for heavy type rail car).	Light-weight metal details : Almg-5, sections ⊏, L and —, assembled by light metal rivets. Diagonals in the casing (as for lightened type bogie rail cars).	Details in anti-corodal or in aviomag (magnesium). Rivetted assembly.
Outside sheeting	Copper steel 2 mm.	Almg-2 2 mm.	Aluman or airal (magnesium).
Brake	— Compressed air (service). — Hand.		— Solenoid (service). — Compressed air. — Hand. — Electro-magnetic on rails (as for rail cars).

TABLE IV.

S. N. C. V. BOGIE RAIL CARS.

Partial weights.

	Heavy inter-town steel type. Kgr.	*Lightened inter-town steel type.* Kgr.	*Light town steel type.* Kgr.	*Light town aluminium type.* Kgr.
Underframe :				
Solebars and cross strechers	2 238	1 350	934	340
Headstock		90	52	40
Platform supports		100	95	30
Floor supports		100	85	30
Gussets		500	440	110
		2 140	1 607	550
Draw and coupling gear	241	180	180	180
Buffer beam	398	230	200	80
	2 877	2 550	1 987	810
Body framework :				
Curved ribs — stanchions	719	450	370	110
Waist rails		300	242	65
Bands		250	90	30
Cornice		100	55	70
		1 100	757	275
Vestibule (4 stanchions)	435	135	135	40
Diagonals		120	56	20
Roof ties		50	36	15
Gussets (brackets and diagonals)		420	89	55
Sheet supports		(*)	20	
	1 154	1 825	1 093	405
Exterior covering	705	450	400	200
Roof covering	480	200	150	150
Ceiling	90	120	80	80
Interior panels	125	80	60	50
Slides and moulding	410	150	100	100
Zinc valence	155	100	80	80
Film boxes	20	30	20	15
	1 985	1 130	890	675

(*) The body framework of the lightened rail car has been reinforced and is stronger than that of the heavy rail car. The outside sheeting is no longer used as support.

TABLE IV. *(Continued.)*

S. N. C. V. BOGIE RAIL CARS.

Partial weights.

	Heavy inter-town steel type. Kgr.	*Lightened inter-town steel type.* Kgr.	*Light town steel type.* Kgr.	*Light town aluminium type.* Kgr.
Body equipment :				
Air brake rigging	477	300	250	210
Compressor	250	350	300	60
Reservoirs and piping	350	200	170	80
Hand brake	200	250	240	220
Sanding gear	165	160	150	40
Controllers	710	370	210	210
Cables		200 820	150 560	150 560
Resistance		250	200	200
Electric installations	200	130	100	100
	2 352	2 210	1 770	1 270
Flooring	520	675	600	550
Partitions and doors	466	300	350	350
Shelves, copper details, equalisers	623	425	250	250
Window lights	725	725	650	600
Footsteps	173	160	160	160
Seats	640	750	470	470
	3 147	3 035	2 480	2 380
Bogies	5 270	3 500	3 480	3 170
Motors and transmission	3 400	3 600	1 950	1 940
Pantograph	100	150	150	150
	8 770	7 250	5 580	5 260
Total	20 285	18 000	13 800	10 800

brake cylinder,
return lever of handbrake,
exterior sheeting,
outside doors,
buffing gear,
drawgear (controllers).

The bogie frame, a single block of cast steel weighing 604 kgr. (1 332 lb.), has been replaced by a frame weighing 460 kgr. (1 014 lb.) made up of solebars with horizontal and vertical ribs (10 mm. [3/8 in.] plates assembled by arc welding). The two solebars are stayed by four crossbeams formed of ⊏ (rolled steel). The bolster in cast steel, weighing 123 kgr. (272 lb.) without the shoes, has been replaced by a bolster which weighs 108 kgr. including the roller bearings and the pivot. This bolster is built up of rolled steel plates, cut by an oxy-acetylene burner.

The *body framework* has been designed to cope entirely with its functions of support and protection. It is difficult to compare the weight of this unit with that of the framework of rail cars of the previous standard construction where these functions were carried out by the framework and the cover plates. The framework of the first prototype town bogie rail car with rivetted underframe, completely welded superstructure in mild steel, weighs approximately 3 200 kgr. (3.149 Engl. tons). The same framework in light metal (Almg-5) with rivetted under frame and superstructure weighs 1 200 kgr. (1.181 Engl. ton).

The brake cylinders have been designed so as to reduce secondary forces. The brackets are at the centre line of the cylinders and are carried on the solebars of the underframe. The brackets are constructed of rolled steel, while the cylinders are of cast iron. The standard cylinder weighs 50 kgr. (110 lb.) and the lightened type cylinder 37 kgr. (81 lb.).

In the theoretical drawing of *the brake bell crank lever,* the centre line of the lever coincides with that of the transmission levers of the brake force to the bogies. In the standard construction this lever consisted of a double bayonet which gave a large secondary bending moment necessitating a large weight of metal. In the lightened construction this lever is duplicated in manner to allow the rods to pass in its theoretical centre line thereby eliminating these bending moments.

The framework of the lightened construction itself fulfils the role of support and protection, and the *exterior sheeting* acts only as a covering; for this, lightweight metal is used. Sheeting of Almg-2 of 2 mm. (5/64 in.) was chosen as the rigidity of this sheeting was sufficient and it had a good appearance. A square metre of steel sheeting 2 mm. thick weighs 15.6 kgr. (34 lb.) while that of Almg-2 of 2 mm. weighs 5.4 kgr. (12 lb.).

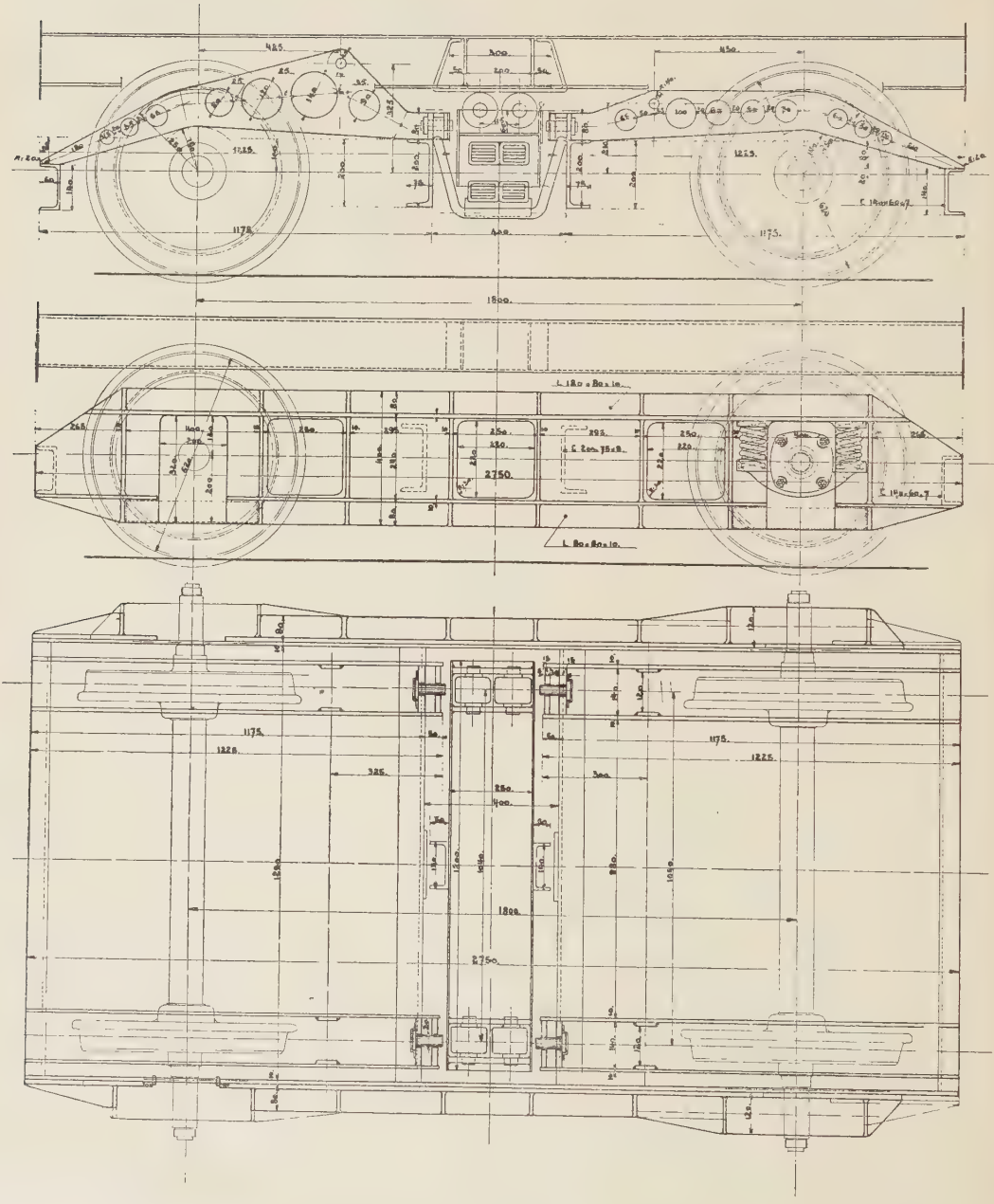
For the *outside doors,* the material to facilitate ease of construction was decided on. The framework is of wood 30 mm. (13/16 in.) thick, and incorporates the window frame. The door pillar is reinforced by steel in form of an I which acts as housing for the rubber strip. The opening of the old single door was only 900 mm. (2′11½″) and it weighed 44 kgr. (97 lb.), while the new lightweight double door has an opening of 1 400 mm. (4′7 1/8″) and weighs 62.5 kgr. (138 lb.).

The lightening of the *buffing gear* was obtained by simplifying the buffing spring support. The new support consists of a block of wood with a circle of iron clamped on at its ends which is used as the housing for the large base of the spring. The other end of the spring presses directly on the buffer beam.

Controllers for the two bogie rail cars having two motors, were built in our workshops as an experiment. These

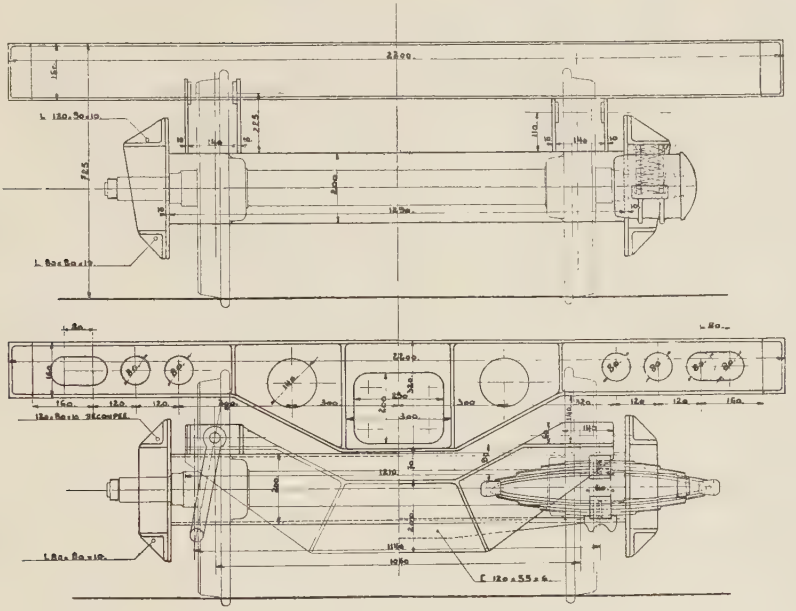
S. N. C. V. — Lightened ty

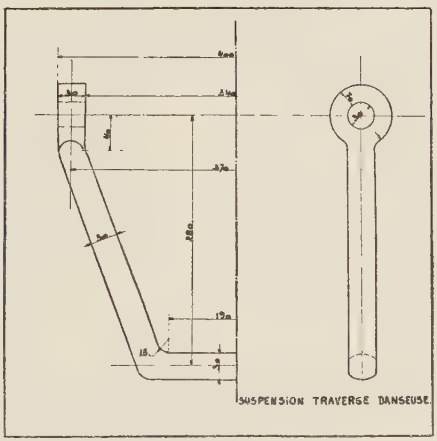
Bogie.



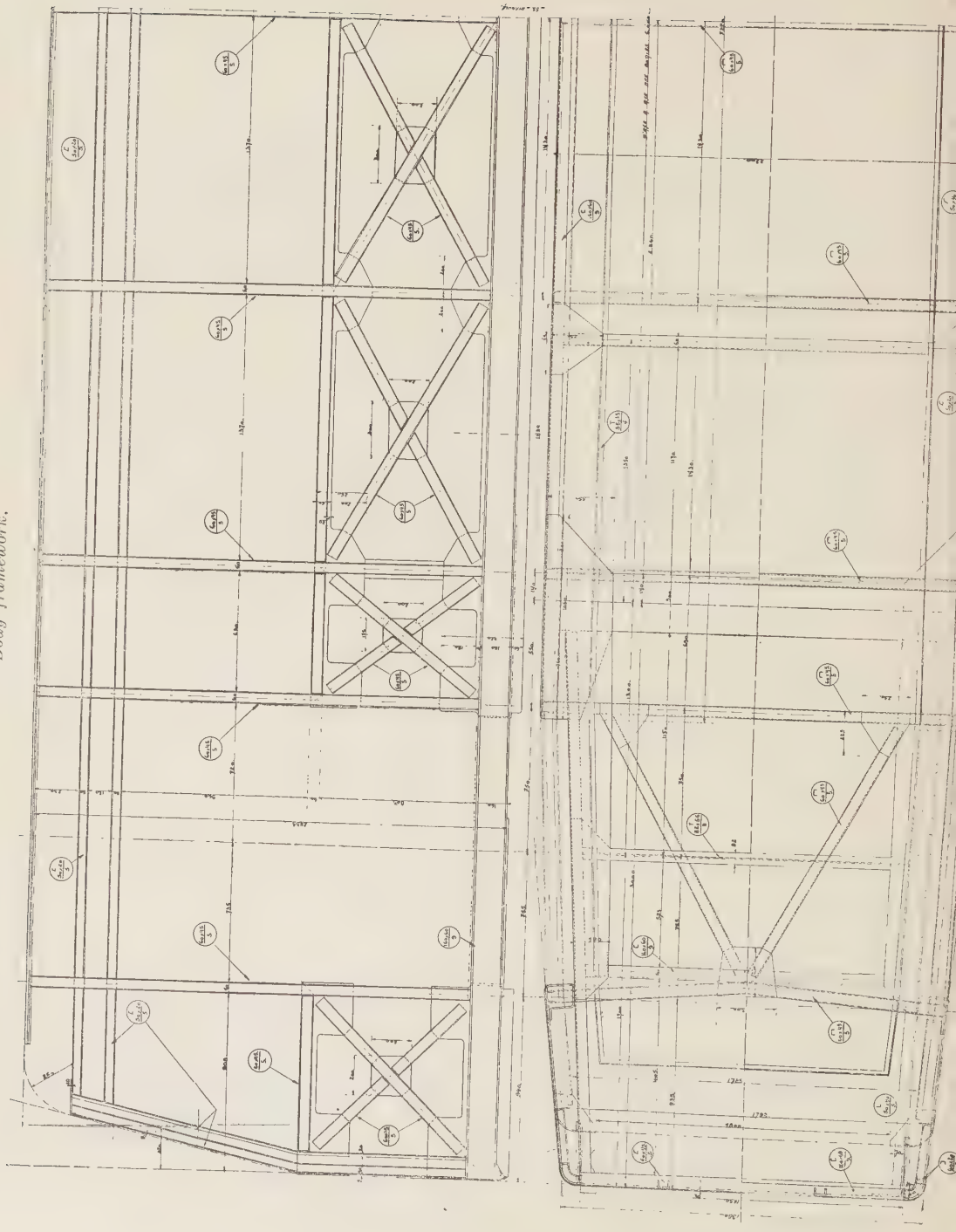
-town rail car.

Bogie. (Continued.)

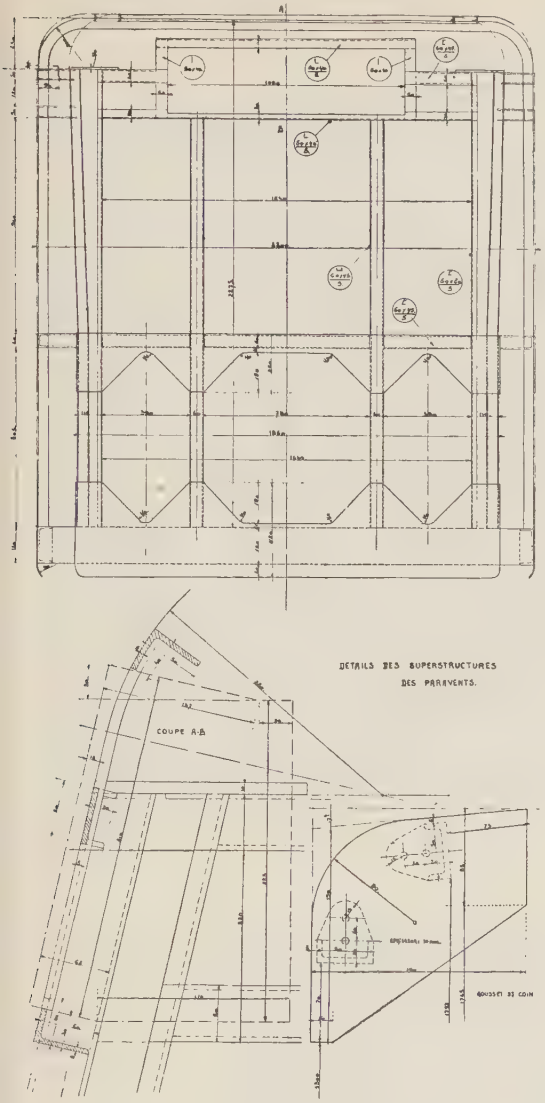




details use the same contactors as the controllers with normal curves, but the gear and mechanism have been lightened. The details in bronze and cast iron have been replaced by built-up details of plate and rolled steel sections electrically welded. In the large details, superfluous material has been removed by the provision of holes and grooves. Standard controllers weigh 135 kgr. (297 lb.) whilst the lightened controller weighs 105 kgr. (231 lb.).



Body framework.



Amongst the peculiarities of construction we should like to draw attention to the lower portions of the four corners of the coaches which have been fitted with *bumpers* protecting the platform solebars and forming details which are easy to rectify after slight collisions. These parts, which are particularly exposed, get many knocks.

In the new lightweight rail cars and trailer cars now being designed, the bumpers have been arranged in front of the leading headstock with a safety joint in the details forming supports for the buffing gear.

In order to *prevent corrosion* where steel sheeting has been used, the following measures have been taken — aerating the slides of the casing, arranging openings for the condensate, and the careful painting of the inside sheeting with lead paint.

With a view to preventing electrolytic corrosion of lightweight metal sheets, these have been fixed on isolating wood packing by means of a screw in lightweight metal or cadmiumised steel.

When in contact with other metals, lightweight metal is first covered with an asphalt base paint. The steel details forming part of the body framework are coated with metal (a deposit of zinc or aluminium). In places where steel and light metal details come in contact, thin sheets of zinc or isolating material are interposed.

At Zurich, steel details are carefully painted after sanding, and lightweight metal details are covered with oxide. In addition, a piece of impregnated cloth is interposed.

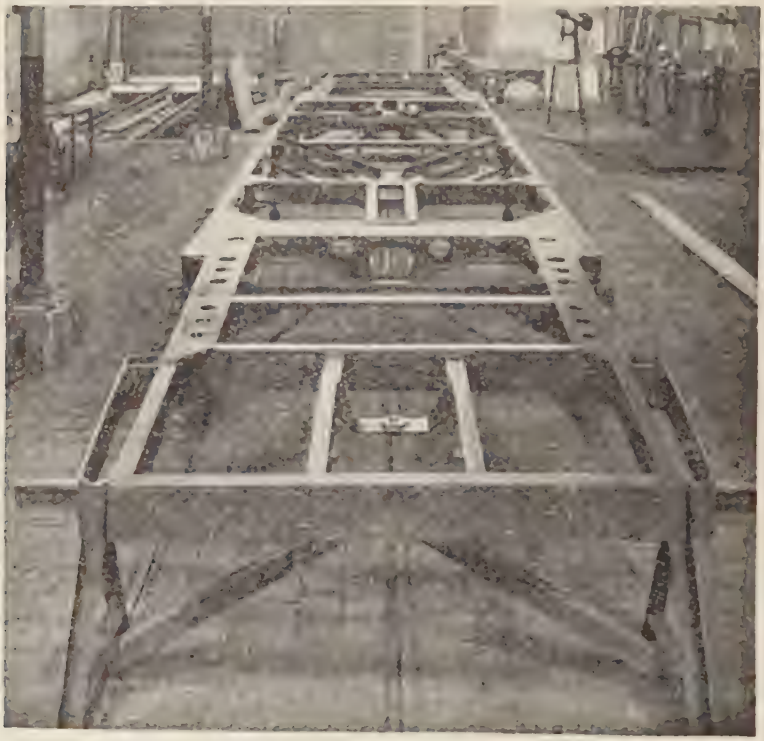
Performance in service.

The two town-type bogie rail cars of lightweight metal which the Belgian National Light Railways put into service, one in May 1945, and the other in April 1946, have stood up perfectly to exceptional and abnormal overloading (160 passengers), and to the collisions in which they have already been involved.

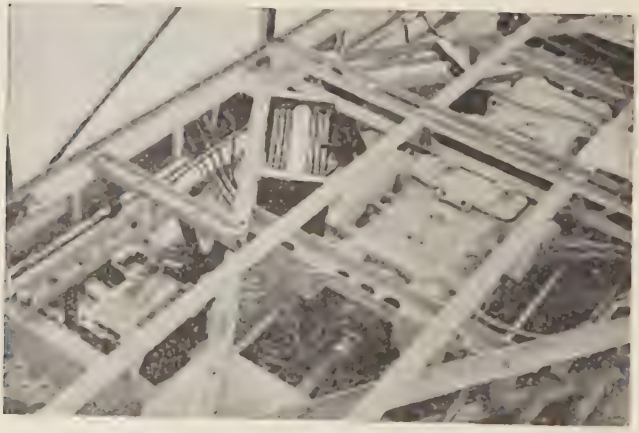
Certain modifications in construction have proved necessary in service, principally concerning the fixing of the body sheeting which must not be affected by deformation of the framework. The E.L.R.T. Co. of Lille has also been obliged to give attention to this matter.

As previously pointed out, the results

Light weight rail cars of the Belgian Light Railways (S. N. C. V.)



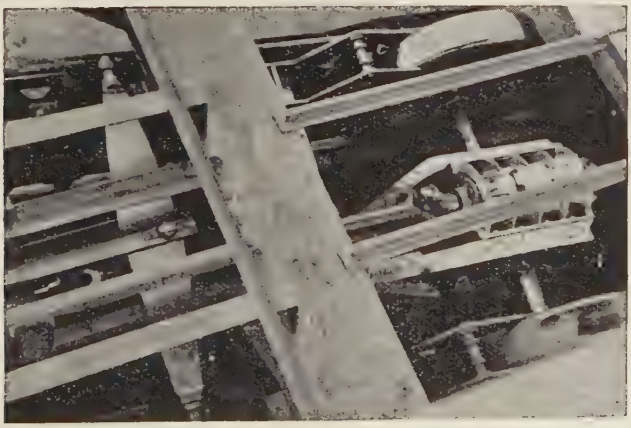
Underframe.



Motor suspension.

Light weight rail cars of the Belgian Light Railways (S. N. C. V.).

Body framework.



Transmission by worm and worm wheel.

obtained with the above-mentioned prototypes have led us to proceed with a more extensive trial with inter-town type bogie rail cars, and bogie trailers, the characteristics of which have been given previously.

Consumption of energy.

Systematic trials have been carried out, the results from which have shown that a reduction of weight of 25 % brings about a reduction in the consumption of energy in the neighbourhood of 10 %.

Conclusions.

A. — Examination of the comparative tables presented show that the present construction tendencies in light railways are the following :

— bogie constructed of mild steel plate and sections,

— use of rubber for springs and certain details of the wheels,

— hollow axles,

— underframe and body framework built up of light metal sections, rivetted in the case of the trailers and town-type rail cars, and of steel sections electrically welded for the intertown rail cars,

— exterior sheeting in lightweight metal,

— omitting interior partitions,

— automatic outside doors,

— ceiling and interior panelling of compressed cardboard or plywood,

— increase in the power and number of revs per minute of electric motors,

— increase in their cooling,

— increase in brake power.

B. — We believe that the trailer and rail cars could be still further lightened when the assembling of the details in special steels can be carried out readily and without difficulty in the normal maintenance workshops and when, in addition, the problem of flexibility of the suspension has been solved.

At the present time, it is necessary to combine special steels, lightweight metals, compressed wood materials, rubber and synthetic products.

C. — It is the present practice to judge the performances of a vehicle by the tare weight per seat or per passenger.

In the case of a rail car, on the other hand, its power is taken into account.

The weight must be the lowest possible, and the power the highest possible. These two facts must not be accepted without reserve, because records can easily be obtained to the detriment of comfort, stability or robustness.

The weight per seat is actually in the neighbourhood of 500 kgr. (1 102 lb.) for the electric rail cars, 370 kgr. (815 lb.) for heavy oil rail cars, and 130 kgr. (286 lb.) for motor buses.

Per passenger, these weights are in the neighbourhood of 250 kgr. (551 lb.) for inter-town type rail cars, 100-150 kgr. (220-330 lb.) for town type rail cars, 185 kgr. (408 lb.) for heavy oil rail cars, and 100 kgr. (220 lb.) for motor buses.

In the case of the trailers, the weights per seat are approximately the following :

Railway express rolling stock	550 kgr.	(1 212 lb.)
Railway suburban rolling stock	400 kgr.	(882 lb.)
Metropolitan	270 kgr.	(595 lb.)
Pneumatic train . . .	210 kgr.	(462 lb.)
Light railway and tram	235 kgr.	(518 lb.)
Motor bus trailer . . .	60 kgr.	(132 lb.)

The powers vary from 15-20 H.P. per tonne empty for electric rail cars, 10 H.P. per tonne empty for heavy oil rail cars and 12 H.P. per tonne empty for motor buses.

The foregoing must obviously be considered with a certain amount of reserve with respect to the value of the figures obtained, nevertheless, they do enable one to realise the improvements and lightening which have been obtained in the construction of electric railcars for light railways and trams.

[625 .25 (.73) & 669 (.73)]

Weight reductions in passenger cars.

(Railway Age, December, 28, 1946.)

With passenger-car specialties contributing approximately two-thirds of the 120 000-lb. total weight of a modern passenger coach a car builder reviewed the limitations placed on the builder in reducing weight. After acknowledging that the selection of equipment cannot be based on weight alone the builder introduced specific data to show the differences in weights between types of the same specialties. Comparisons made showed air brake equipment ranged in weight from 2 180 to 3 120 lb.; heating systems, 1 200 to 1 660 lb.; air conditioning, including battery, generator, fuel, drive and water, 8 720 to 10 800 lb.; booster inverter and transformers, zero to 800 lb.; insulation, 900 to 4 000 lb.; finished floors, 1 000 to 1 600 lb.; partitions, doors and frames, 1 800 to 3 000 lb.; air diffusers, 60 to 850 lb.; parcel racks, 600 to 1 200 lb.; seats, 3 300 to 4 400 lb.; and trucks, 32 840 to 38 200 lb. The total weights of these items ranged from 52 600 to 69 630 lb. or a difference of approximately 17 000 lb.

This builder concluded that the average coach weight could be reduced from 120 000 lb. to 103 000 lb., if this 17 000-lb. saving is applied, without deleting any of the necessary equipment or specialties.

Steel.

One producer of high-strength low-alloy steels used Section 24d of the Specifications for the Construction of Full and Compartment Railway Post Office Cars as the basis for a comparison of the weight savings effected by steels of higher strength than mild steel and an analysis of the weight savings possible in the car body. The analysis dealt with the effects of yield point, elastic stability, compression strength of columns and deflection requirements on weight savings. A chart was included which showed graphically the relation of yield point to weight saving. The conclusion was that while weight reduction is possible with the use of high-strength steels, no hard and fast percentages can be stated for any given yield point. There are many variables which affect the answer. The chart showed that a yield point of 50 000 lb. per sq. in. can give an optimum saving of 36 per cent in comparison with a mild open-hearth steel having a yield point of 32 000 lb. per sq. in. Experience with steels having a yield point of 50 000 lb. per sq. in. indicated that the actual weight saving in practice, where all the variables are integrated, will run about 25 per cent. Assuming this relation to apply likewise to stainless steel with a yield strength of 100 000 lb. per sq. in., this manufacturer expected the practical saving to be $(^{25}/_{36}) \times 68$ per cent or about 47 per cent. It was believed that the saving in weight in the body structure of 45 per cent to 50 per cent in passenger-cars built of high-strength steels in recent years with all the factors of design, construction and steel included, was approaching the limit of weight reduction which the steel in the car body can contribute to the total saving in weight; further reduction must come from the other elements of weight in the car.

A second producer of high-strength steels submitted weight comparisons be-

tween cars of carbon steel and those built of a high-strength steel. In coaches and express cars the saving made by using the high-strength steel was estimated to be 26 000 lb. or 25 per cent, and in baggage cars, 16 000 lb. or 12 per cent. In the latter an additional saving of 10 000 lb. in the trucks was made because the reduced weight of the car permitted the use of four-wheel instead of six-wheel trucks.

The efforts which steel producers have made to reduce the weight of axles was reviewed. After showing that axle weights have been increased to improve strength and safety, a tendency to adopt hollow-bored axles was mentioned. The savings in weight per axle when tubular axle are used in place of solid axles was given as varying from approximately 170 lb. for 5-in. by 9-in. axles to 500 lb. for 6½-in. by 12-in. axles. The savings in percentage range from approximately 25 to 42 per cent.

Aluminium alloys.

Products of interest to manufacturers of passenger-car specialties were listed as being aluminium alloy sheets; plates; shapes, both rolled and extruded, forgings; sand, permanent-mold, and die castings; electrical conductors in the form of cable and bus bar; tubing and piping. The mechanical strength of these products varied from 16 000 to 88 000 lb. per sq. in., dependent upon the alloy, product, and process. Included in the paper was a list of 25 aluminium alloys, their physical characteristics and the form (plate, tubing, forgings, etc.) for which they are suitable. Another table listed some of the car specialties in which aluminium alloys have been used and included 22 general classifications of car parts, the alloys used, and the form in which it is furnished. An addendum to the paper set forth the methods used in the welding of aluminium alloys.

As an example of possibilities of further weight reduction it was mentioned that the utility of aluminium alloy forgings has not yet been explored in connection with truck design.

Air-brake equipments.

Using the type D-22-AR air brake schedule as a basis for making comparisons, specific data on the actual potential weight savings in this equipment was presented. Without the use of weight-saving materials the equipment weighs 2 083 lb. As produced now with war-time restrictions removed it weighs 1 825 lb., a 12 per cent saving, by using aluminium and low-alloy steel in two reservoirs and one bracket. At the request of the customer a further reduction could be made to 1 684 lb., a 20 per cent saving. An additional reduction to 1 287 lb., a 38 per cent saving, could be made by substituting aluminium for cast-iron brake cylinders and slack adjuster bodies. The latter reduction, however entails some precautions, one of which is the requirement for protective measures to avoid rapid wear from flying sand.

Castings.

In discussing weight-saving possibilities in castings three ways of approaching the problem without sacrificing safety were considered. These were by reduction of the loads to be carried, by improved design and by the use of better material.

With respect to a reduction of the loads to be carried the platform center sill castings offered little possibility because the principal loads were specified by the A. A. R. If 5½-in. by 10-in. trucks are used instead of 6-in. by 11-in. trucks about 1 500 lb. in the truck and 325 lb. in the cast-steel parts can be saved. Offsetting factors are the load limitations on trucks for higher speeds and the increase in braking power. As

an example, the 5½-in. by 10-in. axle, which will carry 40 000 lb. at slow speed, is limited to 34 000 lb. at 85 m. p. h. and 32 000 lb. at 100 m. p. h. Higher speed, requiring an increase in braking power from 157½ to 250 per cent, also result in heavier loads on truck parts.

The better design possibilities for irregular shapes were set forth as an advantage of cast structural parts. The use of an integral body center plate instead of separate body center plates with a saving of 160 lb. was given as an example of weight saving by design changes.

In the trucks a reduction from a nine-foot wheel base to 8 ft. 6 in. would save 90 lb. in the truck frame, about the same amount in the equalizers, and some saving in the brake equipment. The use of the beam type brake simplifies truck frame design and saves about 100 lb.

Installation of 13⁶/₁₆-in. roller-bearing boxes instead of 15-in. boxes reduces the frame weight by 30 lb., and a redesigned bolster saves 50 lb.

The more extensive use of low-carbon nickel-alloy steel castings reduces casting weights about ten per cent in comparison with Grade A steel. In regards to better materials it was pointed out that the necessity of casting pads and brackets for the attachment of other parts makes it impractical to reduce all sections of castings and take full advantage of the greater strength of better materials.

Magnesium.

The properties and availability of magnesium were discussed in order to show its suitability for passenger-car applications. Ingot magnesium was said to be the most available metal in the world. Factors tending to offset the higher initial cost of semi-fabricated magnesium parts were simplification of design because its lower density permits the use of thicker sections and the avoidance of complex ribbing and bracing and its machinability. Recently developed arc-welding and hot-forming techniques were mentioned as giving the metal advantages over competitive materials.

The use of magnesium castings in aircraft landing wheels and engine parts during the war and in cast wheels for trucks, buses and heavy ordnance equipment in Europe before the war were cited to show the metal's suitability for applications where shock and vibration are involved. In Europe, tests were also made of cast-magnesium wheel centers for railway equipment because of its sound absorption and vibration-damping characteristics but they were not considered adaptable for use with rim-type brake shoes.

With processes for permanent mold and pressure die castings worked out it was believed that magnesium could save weight in the many small hardware parts and fittings in a passenger car. Its use experimentally in chairs for buses and railway cars was considered as a start in a field where its properties could be utilized to save weight. Attention was called to the co-operative project set up at Purdue University to work with the A. A. R. to demonstrate serviceability and obtain A. A. R. approval for the use of magnesium in various structural forms in railway equipments.

Foundation brake rigging.

Comparisons were made between the weights of foundation brake riggings on cars of the 1920's and early 30's and riggings on cars of 1946 design. The reduction in weight in the brake rigging of sleeping cars, when adjusted to compensate for the difference in braking ratios, was shown to be 3 100 lb., or approximately 36 per cent, as against an 18 per cent reduction in the weight of the complete car. On the same basis the weight of the brake rigging for

1946 coaches was estimated to be 1 300 lb., or almost 20 per cent, less in comparison with a coach of the pre-streamline days having the same light weight at the rail.

These data were introduced to show the contribution made to weight saving by the improvements in foundation brake rigging. The three most important factors influencing the weight saving were listed as the truck-mounted brake cylinder, the utilization of high-tensile materials and close attention to details of design.

Plastics.

Two plastics expected to be of increasing interest to the designers and builders of railroad cars were a low-density core material now being used in the aircraft industry for floors, partitions, and doors in sandwich-type construction, and an acrylic sheeting, which is replacing glass in a number of interior applications where lightness of weight and resistance to shock and impact are important. An example of the strength to weight efficiency of the low-density core material was given by making a comparison of a composite panel with a plate of steel. The composite panel, about 1.08 in. thick, was made of the core material and two faces, each 0.030 in. thick, of spun glass impregnated with a heat-setting resin. The steel plate, 0.245 in. thick, and having the same flexural rigidity as that of the panel weighed 7.63 times as much as the panel. When the two were set up as simple beams and loaded in the center, the steel plate carried 655 lb. before taking on a permanent set, while the composite panel carried 698 lb. The low weight of this core material, the structural strength of panels in which it is used as a core, and its good thermal insulating character were expected to be important factors in the choice of this product for use in railroad cars.

The acrylic resin has a specific gravity of 1.20. In the form of sheets, ranging from colorless crystal through a wide range of colors and with smooth and patterned finishes, it was believed to have interesting possibilities in the interior design of passenger cars. Engineers had worked out attractive effects with indirect lighting and edge lighting and applications where beauty, resistance to impact, and lightness in weight are important were anticipated.

Roller bearings.

One roller-bearing manufacturer believed the reduction in weight of roller bearings and roller-bearing boxes to be dependent upon a further reduction in the truck-frame opening and the fabrication of boxes from rolled shapes and plate. It was said that an available bearing and box, weighing 35 to 40 per cent less than the bearing and box for the wide frame opening now used, would fit into the present standard friction-bearing frame opening. The weight saving was given as approximately 1 200 lb. per car for a 5½-in. by 10-in. axle. Citing the lack of passenger-car journal-box standards as the reason for the limited experience with the fabrication of boxes it was felt that the development of boxes from rolled plate and formed shapes may hold possibilities for further weight reduction. Under the present condition of frame opening the sections in journal-boxes are determined largely by steel foundry practices and it was thought that thinner sections could be used.

Another manufacturer took the same position with respect to roller-bearing journal-box sizes and questioned the need for making the boxes any larger than required for adequately housing and serving the bearing. Lighter-weight material for boxes were believed to offer too many objections to make their use feasible. Better design of the boxes

to eliminate excess material, such as the use of properly placed ribs that would reduce weight with no sacrifice in strength of stiffness, was another approach suggested. The greatest savings were believed to depend on allowing the specialty suppliers to make reductions in the physical proportions that are practical and do not compromise performance and by the standardization of the application requirements.

Couplers.

Because the fundamentals of design for tightlock couplers established requirements exceeding those for Type E couplers no direct comparison of the weights of the two types was considered logical, as the new coupler features added weight. A general comparison of the two couplers, as used on sleeping cars, estimated the weight of the tightlock coupler of high-strength steel to be 2 270 lb. and that of the type E coupler to be 2 160 lb. when made of Grade B steel. In considering these figures emphasis was given to the fact that the tightlock coupler is designed 20 to 25 per cent stronger than the Type E coupler and also, because of its interlocking arrangement, no additional anti-telescoping arrangement is needed. It was suggested that the tightlock coupler permitted a reduction in the diaphragm buffer capacity and a corresponding saving in weight because the latter had to be designed to cushion the free slack between coupler when tightlock couplers were not used.

Insulation.

A modern light-weight car was said to contain, in round figures, approximately 3 000 sq. ft. of insulation at a thickness of 3 in. The density of most insulations used in the past few years has been 2 to 2½ lb. per cu. ft. and prior to that even two and three times that weight. This does not include the weight of heavy facing materials, which are used in most fabrications to hold the product together and perform no other function.

The weight per square foot of unfaced insulation, 3-in. thick, of 2 lb. density is .50 lb. When the same insulation is faced both sides with, as an example, reinforced asbestos paper, the weight is increased to .62 lb. per sq. ft. Therefore, the 3 000 sq. ft. necessary to insulate a car will weigh about 1 860 lb.

An insulation made by one manufacturer requires no facing materials and is produced at a density of one pound per cubic foot at a thickness of three inches, which is equivalent to .25 lb. per sq. ft. Three thousand square feet of this 3-in. insulation will weigh 750 lb. compared to 1 860 lb. for the 2-lb. density material faced both sides with reinforced asbestos paper. The savings thus effected amounts to 1 110 lb.

Air conditioning.

The policy of one manufacturer of air-conditioning equipment of the electro-mechanical type has been that of making weight reductions only if reliability and efficiency are not affected adversely. For these reasons it has continued to make relatively slow-speed compressors rather than use compressors of higher speed and less weight. This company did separate the condenser from the compressor unit with a weight saving of 100 lb. but only after the basic operating requirements were met.

A supplier of steam-ejector air-conditioning equipment showed that their attempt to reduce weight ten years ago by using aluminium was not entirely satisfactory. Recently, this builder has been advised by an aluminium manufacturer that certain parts could be safely made of aluminium and the resulting saving would be approximately 575 lb. Also, certain items might be re-

designed to save 75 lb. and a further saving of 45 lb. might be made by using stainless-steel casing sheets in place of silicon copper. The same manufacturers states that recent developments in compressor design have permitted increases in speed resulting in a weight saving of 225 lb. on equipment of eight tons capacity. The separation of the compressor from the condenser has accomplished a 150-lb. saving.

Seats.

Passenger comfort has required the addition of items such as ash trays, center arms, adjustable footrests, deeper cushions and more luxurious backs, all of which add weight to the seat and have resulted in a seat weighing approximately 185 lb. It was believed that 10 to 15 per cent of this weight can be saved by the greater use of metal in place of wood in the framing, by selecting the covering material with care, by designing the seats with smaller end panels and by the employment of lighter and stronger aluminium and steel alloys.

Steam-heating equipment.

The actual weight reductions submitted by one producer of steam-heating equipment showed a reduction from 3 058.87 lb. in 1925 to 1 331.97 lb. in 1945 based on layouts for a typical coach. This reduction of 1 726.9 lb., or 56 per cent, was compared to the total reduction of nine per cent in dead weight of a coach in the same period and was offered as a reason for the limited extent to which the weight of the heating equipment can be further reduced.

One example of weight saving in post-war equipment was the combining into one regulator the functions of three separate devices formerly used, a change that produced a 50 per cent saving in the weight of the regulator alone. The introduction of new alloys and even plastics was believed to hold possibilities for continued research in the improvement of weight advantages.

Electrical equipment.

An analysis of heating, cooling and electrical equipment showed that the weights varied from 11.5 to 16.1 per cent of the total car weight, the lower figure applying to a car on which a. c. electric power is used at relatively high voltage. If the source of power is removed from the car and located at the head end of the train (steam-turbine generator on the locomotive tender or a Diesel-generator set on a leading car) the weight is reduced to nine per cent of the total car weight. These figures are based on a total car weight of 100 000 lb.

In rotating electrical parts little hope for a substantial weight saving was believed possible. More opportunity for weight economy in equipment structures and refrigerant circuits was anticipated by the use of high-strength steels and light-weight alloys.

A builder of engine-generator sets stated that pre-war designs for mobile service were designed on the basis of 200 lb. per kilowatt, approximately 50 per cent less in weight than industrial equipment. During the war this manufacturer made sets varying from 20 to 200 lb. per kilowatt, depending on the type of service, life expectancy and reliability.

Batteries.

The battery manufacturers commenting on weight savings were all essentially of the same opinion in that storage batteries have about reached the limit of weight reduction in the active material and electrolyte without producing

a battery of shorter life requiring more maintenance. Some reduction in weight may be possible in the containers, covers, trays, connectors, etc., but these parts produce the smallest percentage of the total weight. It was suggested that the battery compartment, weighing from 700 to 1 000 lb., was a possible source of saving. The use of higher voltages (64 to 110 instead of 32) was also suggested because smaller conductors in the wiring and lighter motors and generators might be used.

All of the battery suppliers pointed out that batteries now have a weight per unit of power from one-third to one-half that of batteries of approximately 20 years ago.

A manufacturer of nickel-iron-alkaline batteries listed the weights and ratings of batteries of this type and claimed that a comparison with batteries of other construction would indicate that, depending upon the installed capacity, the saving in weight may be from 1 500 to 2 000 lb. per car.

NEW BOOKS AND PUBLICATIONS.

[625 .14]

CAMPUS (R.). — Honorary Chief Engineer, Belgian National Railways; Honorary Professor, Mons Polytechnic. — **La réalisation d'une voie ferrée de qualité. —** *Les résultats techniques, économiques et sociaux de quinze années d'organisation.* — **The creation of a high-class railway track.** Technical, economic and social results of fifteen years of organisation. — One volume (9 7/8 × 11 3/4 in.), 251 pages, fully illustrated, 1946. — On sale from the Author, 131, Avenue de Broqueville, Brussels.

As the title of the book indicates, the Author gives the results of personal experience in the Permanent Way Department of the Belgian Railways. Readers will find below a short resume of this book, which is lavishly illustrated and full of information for all railways technicians.

In 1924, the Permanent Way Department of the Belgian State Railways decided to vest in a single section all questions relating to the track proper.

The new section replaced the « investigation » method of track maintenance by a more systematic « general overhaul » method, which followed an annual programme.

Track alignment was considerably improved by the introduction of progressive leads into curves and between curves of different radii. Some sections were also marked out with benchstones.

Standardisation of rail types, technical progress in rail joints and switches, revised methods of working and the use of mechanical equipment completed the organisation.

Moreover, stores depots were centralised and large repair shops with modern equipment were established.

Technical results were :

1. — Considerable increases in maximum speeds and particularly in the commercial speeds of trains, by the suppression of numerous speed restrictions previously necessary owing to faulty alignment.

2. — The almost complete suppression of derailments due to track, whether on running lines or in terminal stations.

Direct economic results were :

A considerable reduction in track maintenance costs. In 1938, the last normal working year, these costs, taking into account wage variations, were 50 % of the 1927 costs, corresponding to a reduction of 80 million francs for 1938.

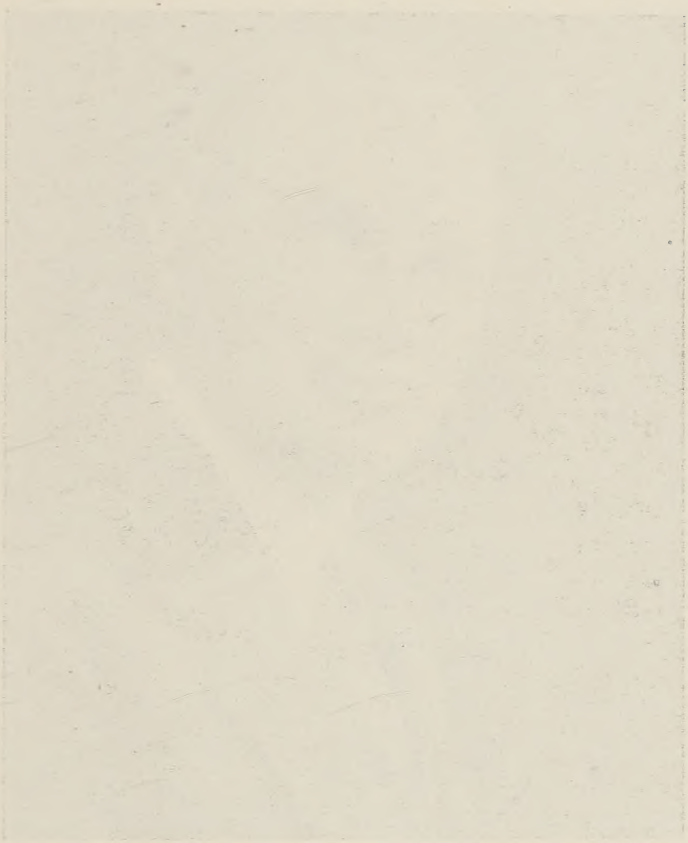
The centralisation of materials reduced by 360 million francs the amount of locked-up capital compared with the pre-war prices; the systematic use of second-hand material considerably reduced the consumption of new material.

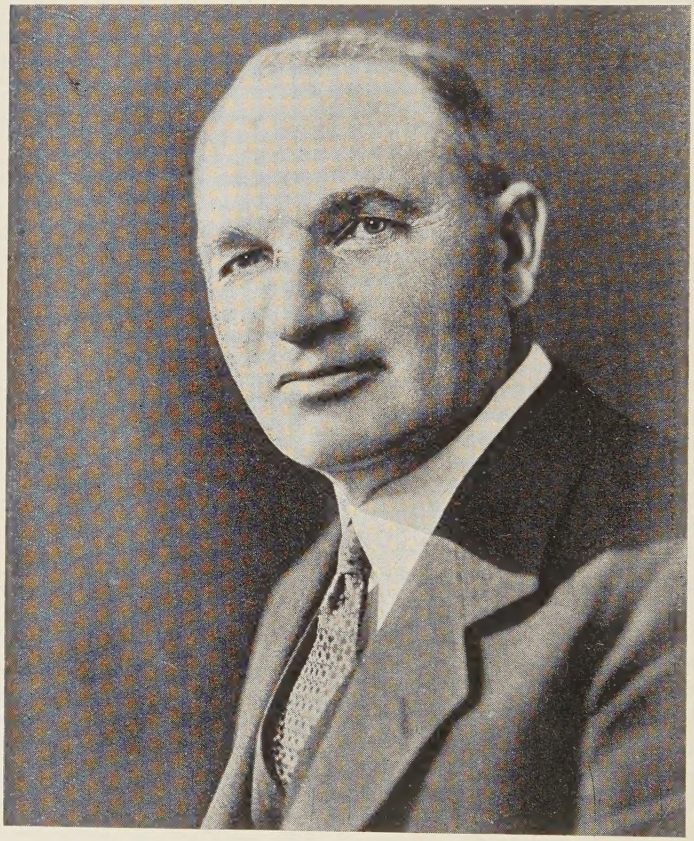
Indirect economic advantages were less wear and tear of rolling stock and track, less damage from the reduced number of derailments and greater regularity of traffic in stations and on open lines.

Finally, gang-work, mechanical equipment and new processes greatly eased the task of the permanent way staff.

The 1946 Charles Lemaire prize was awarded to this work in the Science Class of the Belgian Royal Academy.

There is also an Edition of the book in Dutch.





John Jeremiah PELLEY.

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OBITUARY.

John Jeremiah PELLEY,

Formerly President of the Association of American Railroads.

Former Member of the Permanent Commission of the International Railway Congress Association.

We have learned with deep regret the death on November 12, 1946, at the age of 68, of our former and much devoted Colleague, Mr. John J. PELLEY, eminent member of the Permanent Commission of the International Railway Congress Association.

Mr. Pelley was born at Anna, Illinois, on May 1, 1878. After graduating from high school, he did some special work at the University of Illinois and at the age of 21, entered the service of the Illinois Central Railroad as a station clerk at Anna. In the course of the years following, Mr. Pelley held various positions on that railroad. He became general manager in 1923 and in the following year was elected vice president in charge of operations. In 1926, he was elected president of the Central of Georgia Railway and the Ocean Steamship Company of Savannah, which positions he held for three years. In 1929, he was elected president of the New York, New Haven & Hartford Railroad Company, but resigned in 1934 to become the first president of the Association of American Railroads, which was formed in that year.

Under Mr. Pelley's wise and careful leadership, the Association grew in influence and usefulness, serving as the agent of practically all the Class I railroads of the United States in handling problems common to the industry. There was never any question as to his capacity for leadership nor any doubt of his sincerity and his devotion to the best interests of the industry. As a result of the work done by him and under his direction, the railroads entered World War II with a capacity for service that surprised the nation.

Probably, no greater tribute can be paid to Mr. Pelley than the one included in the citation which accompanied the award of the Medal for Merit, presented to him by President Truman on March 8, 1946, in recognition of the service performed by him in connection with mobilizing the war effort of the railroads. The citation follows :

« John J. PELLEY, for exceptionally » meritorious conduct in the perform- » ance of outstanding services to the » United States as President of the As- » sociation of American Railroads. Un- » der Mr. Pelley's inspiring and aggres- » sive leadership, the Association of » American Railroads throughout the » entire emergency period served to » unite the efforts of the military esta- » blishment and the Nation's principal » railroads in the expeditious and effi- » cient movement of unprecedented » freight and passenger traffic. Mr. » Pelley has been an unfailing source of » wise counsel and advice to the mili- » tary establishment of all phases of » railroad transportation. In the truest

» sense, he personifies the close cooper-
» ation, the untiring energy, and the
» efficient methods which enabled the
» Nation's railroads to achieve their
» outstanding and widely acclaimed
» success in meeting the domestic trans-
» portation requirements of the greatest
» war in history. »

Mr. Pelley also was the recipient in November, 1945, of a certificate issued by the War Department expressing appreciation for the patriotic service performed by him during the war and also received on March 1, 1946, the Treasury Silver Medal for distinguished service in war finance which was given him in recognition of his cooperation in the war finance program.

Mr. Pelley was one of the ancient members of the Permanent Commission of our Association having been appointed in 1935. In spite of his many activities, he always took the greatest interest in our works. On many occasions, he proved himself a true and devoted friend of our Association, always pleased to help in any circumstances.

We will keep the best memory of our much regretted Colleague and wish to convey our sincerest sympathy to his family.

The Executive Committee.